

**Teacher’s Guide**

**Volcanoes: Terror from Below**

***February 2021***

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

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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)

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 and a rubric to assess the graphic organizer.

[Additional Resources 10](#_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. A volcano in the early 1800s triggered global warming.
 |
|  |  | 1. Lava caused the complete evaporation of the water in Hawaii’s largest freshwater lake.
 |
|  |  | 1. Earth’s mantle gets hot enough to melt rocks.
 |
|  |  | 1. Magma originates in Earth’s outer core.
 |
|  |  | 1. Convection in Earth’s mantle is believed to be responsible for breaking up the lithosphere into large plates.
 |
|  |  | 1. Adding water to a crystal at high temperature and pressure increases its melting point.
 |
|  |  | 1. Gases in magma are mostly water vapor, carbon dioxide, and sulfur dioxide.
 |
|  |  | 1. Pumice is a volcanic rock that forms in an explosive eruption.
 |
|  |  | 1. You can estimate the temperature of lava from its color.
 |
|  |  | 1. Scientists monitor earthquakes and volcanic gases to predict eruptions.
 |

# Student ReadingComprehension Questions

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

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

1. What are the different layers of Earth? What are the compositions of each layer? What are the phases of each layer?
2. What is the main chemical found in magma? Based on this chemical, scientists know lava originates from which layer of Earth?
3. Define *solidus*. What is the solidus of the rock in the upper mantle of Earth?
4. Define *incandescence*. Which color of visible light represents lower temperatures? Which color represents higher temperatures?
5. What is *laze*? What is the chemical in laze that contributes to its caustic properties? How does it affect us?
6. Pumice is a common rock formed in volcanic eruptions. How is pumice formed, making it able to float on water?
7. Look up the frequency and energy values of visible light waves. How can we use these values to determine the temperatures of volcano emissions from afar?
8. Explain how flux melting is related to the concept of colligative properties (i.e., freezing point). Compare this to how adding salt to ice changes the ice to liquid water.
9. Explain how it is hard for gases to escape from substances with high viscosity. What makes something viscous? Compare the structures and viscosities of silicon dioxide (in volcanoes) and water.

**Student Reading Comprehension Questions, cont.**

1. Incandescence is used to determine how hot the volcanic emissions are. We can use this procedure in other situations. What would be another time we could measure temperatures using incandescence?
2. In the sidebar at the beginning of the article, it was asked to determine the amount of energy needed to completely boil away the entire lake. Calculate the energy needed using the information given in the sidebar.

**Questions for Further Learning**

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

1. Geologists also use thermal imaging, which measures infrared waves, instead of visible light waves. Where are infrared waves on the electromagnetic spectrum? Research thermal imaging, and explain how it is used to measure the heat of volcano emissions and how scientists use it in other situations.
2. Explain decompression melting. Use a basic phase diagram or molecular structure to explain why melting occurs when pressure decreases, and the temperature remains constant. Water does the opposite! Water melts with increasing pressure. Use phase diagrams and/or the molecular structure of water to explain this.

# Graphic Organizer

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

**Directions**: As you read, complete the graphic organizer below to describe what you learned about any six of the vocabulary concept words in bold type.

|  |  |  |
| --- | --- | --- |
| **Vocabulary concept word** | **Definition in your own words** | **New information you learned about the concept** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

**Summary:** Most people associate volcanoes with Earth science, not chemistry. Write a short description of the chemistry of a volcano.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **What are the different layers of Earth? What are the compositions of each layer? What are the phases of each layer?**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | ***Composition*** | ***Phases*** |
| *Lowest* | *Inner core* | *iron, nickel, sulfur* | *Solid/Rigid* |
|  | *Outer Core* | *Iron, nickel, sulfur* | *Liquid* |
|  | *Lower Mantle* | *Silicate materials* | *Solid/Rigid* |
|  | *Upper Mantle/asthenosphere* | *Silicate materials* | *Solid/Rigid* |
|  | *Lithosphere* | *Silicate materials* | *Solid/Rigid* |
| *Highest* | *Crust* | *Granite and Basaltic* | *Solid/Rigid* |

1. **What is the main chemical found in magma? Based on this chemical, scientists know lava originates from which layer of Earth?**

*Magma is made of molten silicate rocks. This is different from the chemicals in the liquid outer core layer, so magma comes from the solid lower mantle.*

1. **Define *solidus*. What is the solidus of the rock in the upper mantle of Earth?**

*Solidus is the temperature at which rock starts to melt. In the upper mantle, the solidus of the peridotite is about 2000 oC.*

1. **Define *incandescence*. Which color of visible light represents lower temperatures? Which color represents higher temperatures?**

*Incandescence is when visible light is emitted from very hot objects. Yellow is the hottest with temperatures above 1000 oC. Orange is cooler, and red is the “coolest” at about 800 oC.*

1. **What is *laze*? What is the chemical in laze that contributes to its caustic properties? How does it affect us?**

*Laze is short for lava haze. It is a toxic fog that occurs when lava boils away the salty sea water. The salt then reacts with the water in the gas phase, creating gaseous hydrochloric acid. This can affect a person’s breathing, and irritate the skin and eyes.*

1. **Pumice is a common rock formed in volcanic eruptions. How is pumice formed, making it able to float on water?**

*Pumice is made from superheated rock in a volcanic explosion. The gases in the rock escape, which creates lots of holes in the rock, and leaves empty openings and pores. This gives pumice a very low density.*

1. **Look up the frequency and energy values of visible light waves. How can we use these values to determine the temperatures of volcano emissions from afar?**

*Visible light is part of the electromagnetic spectrum, which consists of waves of electromagnetic energy. Each of the colors of visible light have certain frequency and energy values. The higher the frequency (and lower the wavelength), means higher energy. The color with the highest energy (thus creating hotter temperatures) would be blue, followed by green, then yellow, then orange and finally red.*

1. **Explain how flux melting is related to the concept of colligative properties (i.e., freezing point).** Compare this to how adding salt to ice changes the ice to liquid water.

*Colligative properties describe how a melting point or boiling point of a substance is altered when an impurity is added. With flux melting, water from hydrous minerals from the crust works its way down into the hot mantle. The water molecules are impurities, which come between the particles in the mantle rock. This breaks the attractions and causes the rock to liquefy at a lower temperature than normal. This is how we “melt” ice with salt. When we add salt, the salt particles do the same to the attractions between water molecules, causing the ice to liquefy.*

1. **Explain how it is hard for gases to escape from substances with high viscosity. What makes something viscous? Compare the structures and viscosities of silicon dioxide (in volcanoes) and water.**

*Substances with high viscosity are typically larger molecules, with stronger intermolecular forces. Lower temperatures make these intermolecular forces stronger. This prevents gases from moving through these substances, thus requiring more heat and pressure to get through (which causes greater explosions). Silicon dioxide has a higher molecular mass compared to water, and the network covalent bonding is much stronger than the hydrogen bonding of water. Additionally, at cooler temperatures, SiO2 is closer to a solid phase than water.*

1. **Incandescence is used to determine how hot the volcanic emissions are. We can use this procedure in other situations. What would be another time we could measure temperatures using incandescence?**

*We can use these to also determine the heat produced by stars in the universe. Stars emitting different colors would give us an idea of how much heat they produce.*

1. **In the sidebar at the beginning of the article, it was asked to determine the amount of energy needed to completely boil away the entire lake. Calculate the energy needed using the information given in the sidebar.**

*To solve this problem, you need to calculate the heat in two steps. The first step is to find the heat needed to raise the temperature of the liquid water to 100 oC. At this point (step 2), the temperature remains constant, and the heat added is breaking the intermolecular forces between the molecules. We need 2 equations, and we add the heat values together to get the total heat.*

***Part 1: Heating to 100 oC***

*Use Q = mcT, where Q is the heat (in Joules), m is mass, c is the specific heat of water (4.184 J/g oC), and T is the change in temperature (Tfinal-Tinitial)*

*Mass: (1g water = 1 cm3)*

*59423 M3 x 1x106 cm3/1 m3 = 5.9423 x1010 cm3 = 5.9423 x1010 g*

*Q = mcT*

*Q = (5.9423 x1010 g)( 4.184 J/g oC)(100 oC – 18 oC)*

***Q= 2.0387 x1013 J***

***Part 2: Changing to gas***

*Use Q = mass x Hvap. Hvap is the heat of vaporization, or heat needed to convert 1 g of liquid water to steam @ 100oC.*

*40.6 kJ/mol x 1mol/18g = 2.26 kJ/g*

*Q = (5.9423 x1010 g)( 2.26 kJ/g )*

***Q = 1.34 x1011 kJ = 1.34 x1014 J***

***Part 3: Add the 2 heat values:***

*Qtotal= 2.0387 x1013 J + 1.34 x1014 J*

***Qtotal= 1.55 x1014 J***

**Questions for Further Learning**

1. **Geologists also use thermal imaging, which measures infrared waves, instead of visible light waves. Where are infrared waves on the electromagnetic spectrum? Research thermal imaging, and explain how it is used to measure the heat of volcano emissions and how scientists use it in other situations.**

*In the article, a scientist uses a thermal camera to determine the temperature near a volcano. These can be used in place of using incandescence for measuring temperatures. Thermal cameras measure infrared waves. These waves are just outside of the visible spectrum. Infrared waves are emitted from heat. A thermal camera measures the magnitude of infrared rays and translates these measurements to temperature values. See this link for info:* [*https://bit.ly/3oBecj9*](https://bit.ly/3oBecj9)*.*

1. **Explain decompression melting. Use a basic phase diagram or molecular structure to explain why melting occurs when pressure decreases, and the temperature remains constant. Water does the opposite! Water melts with increasing pressure. Use phase diagrams and/or the molecular structure of water to explain this.**

*Decompression means lessening the pressure on a substance. When the pressure decreases, the molecules of the substance are allowed to spread apart from each other, thus weakening the attractive forces between the molecules. This makes the substance turn to liquid.*

*Water does the opposite. Water molecules, because of its structure, form rings when they solidify. When pressure is applied to the solid water, the rings are broken, causing the water to liquefy.*

*Students can use phase diagrams to show this. In the phase diagram below, following the blue arrow we can see that when the pressure is increased and the temperature stays constant, we see that ice is melted – going from a solid to a liquid.*



**Liquid**

**Ice (solid)**

**Water vapor (gas)**

 **Credit:** CK-12 Foundation - Christopher Auyeung

**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 |

# Additional Resources

**Labs and demos**

**The Lovely Lava Lamp:** In this lab, students add food coloring to a mixture of oil and water and record their observations. They then add an Alka-Seltzer tablet, record their observations and answer a series of questions about the chemical and physical changes that took place.

<https://teachchemistry.org/classroom-resources/lava-lamp>

**How to Make a Cartesian Diver:** In this activity, students create your own cartesian diver using a pipette and learn how to make a transform your diver into squidy diver. <https://buggyandbuddy.com/cool-science-kids-make-cartesian-diver/>

**Lessons and lesson plans**

**Teaching Earth Chemistry – Chemistry Solutions Article:** This article looks at how plate tectonics operate. Use various visuals to collect evidence to complete a data table that teachers or students can use to explain conclusions about our questions: Why do some volcanoes erupt explosively while others usually do not, and how does earth chemistry lead to this result? <https://teachchemistry.org/periodical/issues/march-2020/part-3-teaching-earth-chemistry>

**Investigating how the Chemistry of Plate Tectonics Affects Volcanoes:** In this activity, students will learn about the impact chemistry has on plate tectonics and volcanoes. Students will analyze graphs and charts in order to better understand these topics during this investigation. <https://teachchemistry.org/periodical/issues/march-2020/part-3-teaching-earth-chemistry>

**Projects and extension activities**

Infrared thermometers are popular now because of COVID-19. Have students use (or teacher demonstrate) some common infrared thermometers in class, and if possible, compare their readings with a basic lab thermometer. How similar are the readings? Read through the user manual or research online to see what the accuracy claims are for these thermometers.

**Other Resources**

**Mount Kilauea Volcano Eruption, BBC Earth:** Volcanos are certainly destructive, but without them, there would be no breathable atmosphere, oceans, land, or life. <https://youtu.be/L4qDgsyFw7M>

**How Does Thermal Imaging Work?** <https://bit.ly/3oBecj9>

**Compound Chemistry Infographic: Lava and Volcano Gases** <https://cen.acs.org/content/dam/cen/96/28/09628-feature2-volcanoes.jpg>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Energy & Thermodynamics
* States of Matter
* Quantitative Chemistry

**Correlations to Next Generation Science Standards**

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

**HS-ESS2-3**

Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection.

**Disciplinary Core Ideas:**

* ESS2.A Earth Materials and Systems
* ESS2.B: Plate Tectonics and Large-Scale System Interactions

**Crosscutting Concepts:**

* Cause and effect
* Energy and Matter
* Systems and System Models
* Stability and Change

**Science and Engineering Practices:**

* Analyzing and interpreting data
* Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

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

**Correlations to Common Core State Standards**

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

**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 seen a volcano. Ask students how they think volcanoes form.
	+ As they read, students can find information to confirm or refute their original ideas. *Do not tell students the answers prior to reading.*
	+ After they read, ask students what surprised them about information in the article.