

Soda Bottle Volcano

Living with a **VOLCANO** in Your Backyard
MOUNT RAINIER



Grade Level: 5-8

Learner Objectives:

Students will:

- Understand the important role of gases in providing energy for explosive volcanic eruptions
- Understand how pressure affects gases
- Learn how gases influence the texture and appearance of volcanic rocks

Setting: Outdoors or uncarpeted class-room with a tarp or plastic floor covering

Timeframe: 15 minutes; 25 minutes

“Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption”

“Making Your Own Volcanic Eruption—Option 1 or Option 2”



**Living with a Volcano in Your Backyard—
An Educator’s Guide with Emphasis on
Mount Rainier**

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Examine how gases provide for explosive volcanic eruptions by making comparisons to gases in a soda bottle and by conducting a carefully controlled “eruption” of baking soda/vinegar or soda water.

Teacher Background

Water—The Surprisingly Essential Ingredient in Explosive Volcanic Eruptions

Hot *magma* and water vapor seem incompatible. Yet, water vapor (H₂O), carbon dioxide (CO₂), sulfur dioxide (SO₂), and lesser amounts of rarer gases take up as much as ten percent of the magma (by weight) that lies beneath some Cascade volcanoes. These gases are important because their expansion provides the energy that blasts magma to Earth’s surface during an explosive volcanic eruption.

About 80 kilometers (50 miles) below the Earth’s surface, water sweats off the subducted oceanic plate and promotes the formation of magma, which then rises into the Earth’s crust (see **Surrounded by Volcanoes** for further detail). Water vapor and other gases, elements and minerals coexist as a mixture of molten or partially molten magma having a texture similar to hot oatmeal (see **Magma Mash** background section for further details).

A Magma Chamber is Like a Pot of Dessert Pudding

Imagine magma as home-cooked pudding bubbling in a pot topped by a tight lid. Some of the ingredients in the pot combine as they cool; this is similar to the process

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Soda Bottle Volcano

Chapter 1

Soda Bottle Volcano continued...

Materials:

“Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption”

- Graphic *“The Role of Gas Bubbles in an Eruption”*
- Teacher Page—Narrative *“What Makes a Volcano Erupt?”*

“Making Your Own Volcanic Eruption—Option 1”

- Graphic *“Soda Bottle Volcano”*
- Clear plastic bottle of tonic or seltzer water or other sugarless clear soda (those containing sugar are sticky)
- Paper towels
- Tarp or other plastic floor covering (optional)

“Making Your Own Volcanic Eruption—Option 2”

- Graphic *“Soda Bottle Volcano”*
- 8 or 9 oz clear plastic soda bottle for each student
- Permanent ink marker pen
- 1 box baking soda
- 2 gallons vinegar
- 1 box tissue
- Spoon
- Paper towels
- Tarp or other plastic floor covering (optional)

Vocabulary: Conduit, magma, magma chamber, exsolution, fumaroles, pumice, scoria, throat, volcanic ash

Skills: Demonstrating, inferring, observing, predicting

of elements combining to form minerals. During this process, tiny bubbles of gas separate from their more solid surrounding neighbors. Since gases are lighter, they rise to the top of the pudding (or magma). As gases separate progressively from the pudding, bubbles rise, expand, and form a gas-rich layer at the top of the pot (or *magma chamber*).

The Pot Boils Over

The pressure of rising gases eventually forces the pot lid to vibrate. Puffs of steam break out between the pot and lid in the same way that volcanic gases escape the top of a magma chamber through cracks and openings in surrounding rocks.

The upward pressure of gases eventually exceeds the downward pressure exerted by the lid, and the pudding and gases pour over the side of the pot and onto the stovetop. This is the same concept as lava escaping across the slopes of an erupting volcano. Some of the pudding propels explosively out of the pot and splatters everywhere, similar to magma erupting from a volcano as rock fragments or ash.



For more information on how minerals form in magma, see the Magma Mash activity.

Soda Bottle Volcano continued...

Benchmarks:

Science:

- 1 – The student understands and uses scientific concepts and principles
 - 1.1 – Use properties to identify, describe, and categorize substances, materials, and objects, and use characteristics to categorize living things
- Classify rocks and soils into groups based on their chemical and physical properties; describe the processes by which rocks and soils are formed

Gas Bubbles Determine the Texture of Volcanic Rock

During an explosive volcanic eruption, gases escape into the atmosphere; however, some become trapped in the quickly cooling magma. The erupted magma, in the form of ash and lava, may contain bubble holes from the former presence of gases. The resulting rocks appear similar to foam from a bottle of soda. These rocks are called *pumice* and *scoria*. Sometimes the gas-rich magma erupts so explosively that it breaks into tiny fragments known as *volcanic ash*.

Sidebar 1

Fumaroles at Mount Rainier

Hot gases often mix with groundwater before venting to the surface as fumaroles. Steam and gases that spew from the fumaroles make the air smell unpleasant and deposit colorful minerals on Earth's surface. Active fumaroles are found at most Cascade volcanoes.

Fumaroles are evidence that Mount Rainier is an active volcano. Inside Mount Rainier's summit craters, heat from fumaroles has melted out a system of narrow ice caves and a sub-ice lake, possibly the highest lake in the United States. Temperatures at the hottest fumaroles range between 70–90°C (150°–200°F) and produce enough heat to keep some parts of the summit craters snow-free year round. Early climbers used the ice caves as shelter. They described huddling around the fumaroles and feeling scalded on one side and frozen on the other! Fumaroles exist also on the upper flanks of Mount Rainier at Disappointment Cleaver, Willis Wall, Sunset Amphitheater, the South Tahoma headwall and the Kautz headwall. These fumaroles have lower temperatures due to increased dilution by groundwater. Some gases rise to the surface through thermal springs near Winthrop and Paradise Glaciers, the Nisqually and Ohanapecosh Rivers, and Longmire Springs.



For more information on volcanic ash, pumice, and scoria, see the Tephra Popcorn activity.

Soda Bottle Volcano continued...

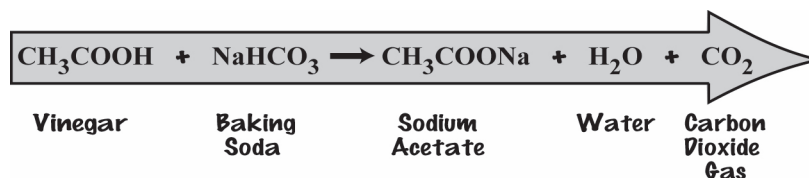
How the Soda Water Experiment is Like a Volcano

The wide body and narrow neck of a soda bottle roughly resemble the shape of a magma chamber and the *conduit* or *throat* within a volcano. The pressurized soda water represents gas-rich magma that is under pressure from overlying rocks.

Carbonated beverages get their fizz from the gas carbon dioxide. When the bottle is capped, carbon dioxide dissolves within the soda from the pressure exerted on it. It also occupies the void between the surface of the liquid and the cap. Shaking the bottle adds energy and causes gas in the soda water to separate, forming tiny bubbles throughout the liquid. Formation of the bubbles increases pressure inside the bottle. Quickly removing the cap releases this pressure, and the bubbles immediately expand. Forced up the narrow neck, the fluid and bubbles burst from the high-pressure environment of the bottle to the lower pressure of the atmosphere. Bubbles of water vapor and other gases within magma undergo a similar progression. They are initially dissolved in magma, then depressurization of the magma chamber frees the bubbles from the magma in a process called *exsolution*. The bubbles rise to the top of the *magma chamber*. Pressure from the gas bubbles propels both the magma and gas up the conduit. The gas bubbles now rapidly expand to thousands of times their original volume when escaping up the conduit to the top of the erupting volcano.

How is the Vinegar and Baking Soda Eruption Unlike a Volcano?

Combining baking soda and vinegar causes a chemical reaction that quickly produces carbon dioxide bubbles:



This demonstration differs from the processes within real volcanoes, because the gases that cause explosive eruptions do not result from sudden chemical reactions. In the soda water and baking soda/vinegar experiments, carbon dioxide acts as the main gas driving the explosion. In most volcanic eruptions, water is the principal gas driving an explosive eruption and not carbon dioxide.

Sidebar 2

Why Volcanoes Stink

Two of the principal gases released from volcanoes, water and carbon dioxide, are odorless. Volcanoes also release sulfur dioxide and hydrogen sulfide into the atmosphere in lesser amounts. These gases have strong smells. Sulfur dioxide has an odor similar to struck matches. Hydrogen sulfide smells like rotten eggs or sewer gas and can be sensed even in low concentrations.

Procedure

Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption

Explore how gas molecules respond to pressure using an illustration and classroom demonstration.

1. Demonstrate how gas reacts in different pressure conditions. Divide the class into two groups. One group will act as “rock walls” and the other group will act as “gas molecules.” The gas molecules should always be in random motion.
2. Instruct the “rock walls” to form a tight circle around five of the “gas molecules.” Further instruct students (walls) not to change size of circle once formed.
3. Ask the five students (gas molecules) in the center of the circle to move randomly from one side of the “rock walls” to the other. They should have a difficult time doing this in such a tight space.
4. Add one student at a time from the “gas molecules” group to the inside of the circle until there are no more students (gas molecules) left. Students should have a hard time squeezing into the circle if the “rock walls” circle has not changed its size.
5. Tell everyone to “Freeze.”
6. Explain to the students that they have just demonstrated what happens in a magma chamber. Gases rise out of the magma and accumulate at the top of the chamber. As more gases accumulate, the pressure increases. Eventually the pressure of the gas exceeds the pressure of surrounding rock, so the gases must escape up the magma conduit.
7. Instruct the “rock walls” to enlarge the circle while the “gas molecules” remain in place.
8. Tell the “gas molecules” to mingle so that they move throughout the entire space. This is what happens when pressure is decreased; gases expand to fill up space.
9. Instruct two people in the “rock wall” to open a hole in the circle. This allows the “gas molecules” to escape rapidly, as in a volcanic eruption.
10. Show students the ***“The Role of Gas Bubbles in an Eruption”*** graphic. Use the ***“What Starts and Eruption?”*** narrative to discuss the graphic.

Making Your Own Volcanic Eruption

Examine the role of gas in explosive volcanic eruptions by using either **Option 1** (soda water) or **Option 2** (a baking soda/vinegar mixture in a bottle). This activity can be done as a demonstration or in small student groups.

Option 1: Soda Water Eruption

1. Divide students into groups of three or four.
2. Provide each group with an unshaken bottle of soda water with the label removed.
3. Instruct students to examine the bottle and discuss their observations. They should pay close attention to the number and size of bubbles in the soda water and also to the firmness of the sides of the bottle.
4. Have students shake the bottle vigorously for about 30 seconds.
5. Instruct students to examine the appearance of the bottle's contents. How the bubbles change in size and location within the bottle? Where are they smaller? Where are they larger? If froth forms at the top of the bottle, explain that small bubbles in the soda water expanded after shaking to form this froth.
6. Ask students to look at the bulging cap on the bottle and feel the firmness of the sides of the bottle. Why has this happened?
7. Instruct students to predict what would happen if the bottle is shaken and uncapped immediately afterward.
8. Tell students to imagine the bottle is a volcano, with the opening as the volcanic vent.
9. Ask students to shake the bottle rapidly and open it with the top directed AWAY from viewers.
10. Discuss the similarities between gases in the soda bottle and those in a magma chamber beneath an erupting volcano.
11. On the empty soda bottle, draw a volcano with magma conduit (throat), magma chamber, and surrounding rocks. Use the "**Soda Bottle Volcano**" graphic as a model. Draw circles to indicate how bubble size changes with reduction of pressure.
12. Refer to the graphic and ask students to point out which features they played during the human molecule exercise earlier in this activity.



"Making your Own Volcanic Eruption" can be messy, so do the experiment outside or in an easy-to-clean area.

Soda Bottle Volcano *continued...*

Option 2: Vinegar and Baking Soda Eruption

1. Explain to students that they will be making baking soda/vinegar volcanoes. The baking soda reacts with vinegar to form carbon dioxide gas. Carbon dioxide, sulfur dioxide, and water vapor are common volcanic gases. Gases building up in the magma chamber provide the main trigger for volcanic eruptions.
2. Divide the class into groups of three or four.
3. Give each group an empty eight or nine-ounce soda bottle. Using the “*Soda Bottle Volcano*” graphic as a model, have students draw a volcano on the empty soda bottle showing the magma conduit (throat), magma chamber, and surrounding rocks. Draw circles to illustrate bubbles that enlarge as they rise because of reduction of pressure. Note that if you use larger bottles, you need to raise the volumes of ingredients proportionally.
4. Preferably in an outdoor setting, instruct students to prepare their makeshift volcano by pouring vinegar into the bottle to a depth of about eight cm (three inches), so that the bottle is at least one-third full.
5. On single sheets of tissue, each group should pour a heaping teaspoon of baking soda so that the tissue can be rolled up and squeezed through the bottle neck quickly. Students **SHOULD NOT** push the baking soda bundle into the bottle until instructed to do so.
6. Before students activate the chemical reaction, inform them to make some observation during the experiment. Each group should look, listen, and feel for an increase in pressure within the bottle. They should watch the gas bubbles and note any increase or decrease in size. Additionally, they should keep an eye on the volume of gas bubbles produced during the remainder of the experiment.
7. Keeping the bottle pointed **AWAY** from viewers, students push the baking soda bundle into the bottle of vinegar. They should immediately place a hand over the top of the bottle and try not to let any gas escape. They should feel the pressure build and hear the escaping gases make hissing sounds similar to what you would hear near a real volcanic vent.
8. Instruct students to shake the bottle for 10-20 seconds with their hand firmly over the opening of the bottle. The gases inside the bottle will dramatically expand, force their hand away, and propel a foamy froth into the air and down the sides of the bottle.
9. How did the students’ results compare to that of a real volcanic eruption? Did the pressure increase? How do they know? How was covering the top of the soda bottle similar to a closed magma conduit? What happened to the size and quantity of the gas bubbles after the eruption?



Soda Bottle Volcano *continued...*

Adaptations

- ◆ Ask students to use different shaped containers that represent the magma chamber and conduit of a volcano. How does shape affect the eruption results?
- ◆ For younger students, direct them to draw lines on a piece of paper that divide it into six sections. Ask students to draw a before, during, and after experiment picture in squares 1, 2, and 3. Instruct students to draw pictures in squares 4, 5, and 6, of what a volcano would look like if it behaved like the experiment represented in squares 1, 2, and 3 respectively.

Extensions

- ◆ Instruct students to make a four-page book that illustrates gas bubbles increasing in size as the magma rises in the Earth and ends with a volcano erupting.
- ◆ Search for the link between volcanic gases and acid lakes. Ask students to use the Internet to research this topic. Some examples of lakes containing volcanic gases include Lake Nyos, Cameroon; Kawa Ijen, Indonesia; and Santa Ana, El Salvador.
- ◆ Direct students to explore Internet-based computer programs that simulate volcanic eruptions. Note the list of selected computer programs in Internet Resources.

Assessment

Look for evidence of students' understanding of the following concepts: that magma contains gases under great pressure; that gases provide the energy for volcanic eruptions; that gases influence the texture and appearance of volcanic rocks. Look for students' recognition of the differences between the baking soda and vinegar eruption, which is based on chemical reactions, and an actual volcanic eruption, which is based solely upon pressure release.

References

- Decker, R. and Decker, B., 1998, *Volcanoes*: W.H. Freeman and Company, New York, 321 p.
- Francis, P., and Oppenheimer, C., 2003: *Volcanoes*: Oxford University Press, 536 p.
- VanCleve, Janice, 1994, *Volcanoes—Mind-boggling experiments you can turn into science fair projects*: John Wiley and Sons, New York, 89p.



Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.



What Starts an Eruption?

Narrative

Gases, such as water vapor, CO₂, SO₂, and other rarer gases, are the driving forces that power explosive volcanic eruptions. However, gases are not the only players in a volcanic eruption. The size and explosiveness of an eruption are also controlled by the amount of magma in the magma chamber, the magma's chemical composition, and the pressure change in the narrow conduit that leads to Earth's surface.

Magma

Deep below the surface of the earth, the subducting plate's temperature increases. Water rises out of the sinking slab, migrates into the surrounding hotter mantle rock, and initiates melting. The molten rock is called magma.

Pressure

Within the Earth, the weight of rock causes pressure to increase with depth (imagine the weight, or pressure, on your body if a million rocks were sitting on top of you!). The greater the depth, the greater the pressure. Pressure can cause gases such as water vapor and carbon dioxide to dissolve in magma at great depth, and then to come out of the magma to form bubbles, like those in a carbonated drink, as the magma rises and pressure decreases.

Magma Chamber

The magma chamber is a zone of molten and partially molten rock that exists beneath a volcano. The top of the magma chamber at Mount Rainier is about eight kilometers (five miles) below the Earth's surface and is only a few kilometers wide. As gas bubbles accumulate, the upward pressure increases, forcing cracks in the rocks to widen, often in the direction of Earth's surface. For magma to erupt from a volcano, this upward pressure must exceed the downward pressure that is exerted by the eight-kilometer (five mile) thick load of rock overhead.

Magma Conduit

With the accumulation and rise of bubbles through the magma chamber, the pressure increases and will eventually become great enough to break through overlying roof rocks, creating a conduit to the surface. Magma escapes through the "super highway" of the volcano, known as the magma conduit or throat. This long, narrow opening leads from the top of the magma chamber to the Earth's surface. Near the surface, the throat of Mount Rainier is only ten to fifteen meters (33 to 50 feet) wide and is currently filled with solid rock.



What Starts an Eruption?

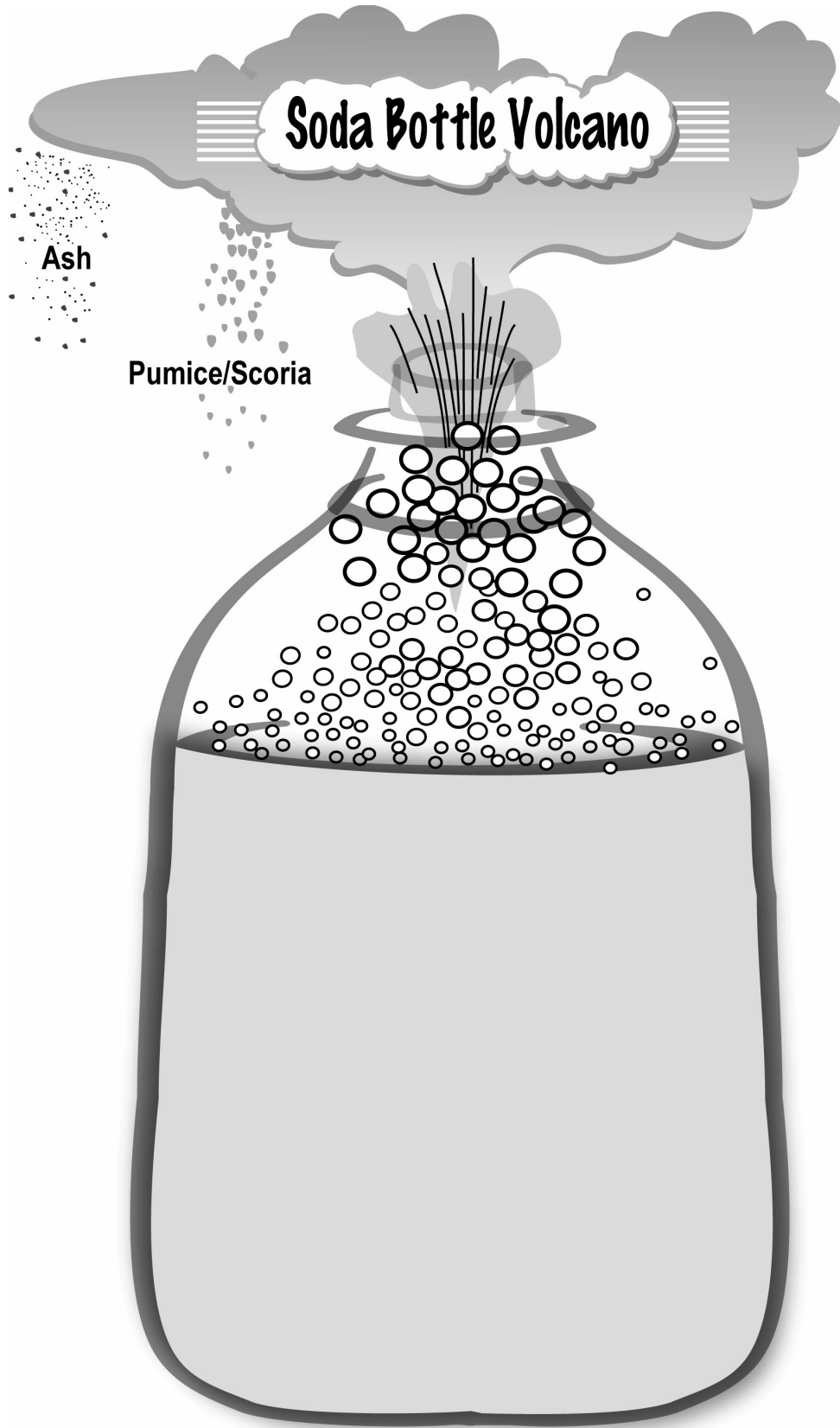
Narrative—continued...

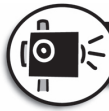
As gas bubbles rush up the magma conduit, the pressure declines, causing the bubbles to expand rapidly. They can expand to thousands of times their original size! The rapid expansion of gas bubbles propels the magma and gas up the conduit. Within minutes, the volcano erupts, explosively spewing hot lava and tephra into the air. Lava can be jetted thousands of feet into the air. Eventually, if the magma is “runny enough,” the gas bubbles escape easily; and instead of exploding, magma pours down the flanks of volcano as a lava flow.

Vents and Fumaroles

Cracks and fractures in the rock surrounding the conduit can also allow gases to escape from the magma through vents and fumaroles. If enough gas escapes, the character of the eruption will be changed from explosive to non-explosive.







The Role of Gas Bubbles in an Eruption

