Activity Overview

Students design an experiment to determine the volume of gas dissolved in a carbonated beverage. Their experience with the soda can is used to help them to think about the gases that volcanoes release into the atmosphere. They learn about the common gases dissolved in magma and released during volcanism. This enables students to understand the connections between the geosphere, atmosphere, hydrosphere, and biosphere.

Preparation and Materials Needed

Ask students ahead of time to assign one student per group to bring a can of soda to class. Prepare the other materials that students will need for this investigation.

This is an open-ended investigation, but you will supply the materials that students will use to develop their experimental designs.

If you do not have modeling clay (used to partially seal the opening of the soda can and hold the hose in place), you can substitute masking tape or duct tape. See **Teaching Tips** on the following page.

Materials

- Can of soda/pop (full and unopened)
- Heat source (Bunsen burner setup or hot plate)
- 1-L Pyrex® beaker (for water bath)
- Rubber tubing (about 50 cm)
- 500-mL beaker
- Modeling clay (to partially seal soda can opening)
- Safety goggles
- Plastic container (shoebox size)

Think about It

Student Conceptions

The question in **Think about It** should provide information about your students' ideas and knowledge of volcanic gases. Likely student responses will include smoke, gas, steam, and water vapor. Hold a very brief discussion about their ideas.

Answer for the Teacher Only

Refer to the **Background Information** for this activity.

Teaching Tips

Students have collected as much as 350 mL of gas from a 12-oz. can of soda. Be sure to check their experimental designs to make sure that they are not inserting the rubber tubing into the soda—it should remain above the level of soda in the can so that it collects gas from above the liquid.

Alternative approaches or modifications to this activity successfully tested by *EarthComm* field test teachers include the following:

- Use a 20-oz. plastic bottle of soda. Prepare the appropriate size one-hole rubber stopper by inserting a glass tube into the stopper and attaching rubber tubing to the top of the glass tube to transport gas from the bottle to the collection beaker. Once this is prepared, students can quickly open the bottle and insert the rubber stopper into the top of the bottle. This minimizes the loss of gas from the soda.

- Place a latex safety glove over a soda can. Use a sensitive electronic balance to find the mass of the soda can plus the glove (be sure that the can is free of condensation, i.e., wiped dry). Without removing the glove, carefully open up the soda can. Place the can in the hot water bath. Students will observe the glove inflating. When the glove no longer appears to expand, cut a hole in the glove to allow the gas to escape. Find the mass of the can and glove. Students will note a decrease in mass, which represents the mass of carbon dioxide gas that has escaped. Challenge students to determine the volume of the carbon dioxide that has escaped using the density of carbon dioxide gas at normal temperature and pressure (1.8×10^{-3} g/cm^3).

- Prepare a rubber stopper (for an Erlenmeyer flask) into which a glass tube has been inserted. Connect the rubber tubing from the gas collection device to the glass tube in the rubber stopper. Prepare the water bath. Open the can of soda and immediately pour it into the flask, place the rubber stopper on the flask, and place the device into the hot water bath. This also acts to reduce the amount of gas lost to the atmosphere.

- Use a graduated cylinder rather than a beaker to collect the gas because it allows a more accurate measurement of gas volume.

- Put a large balloon over the top of the soda can. Open the can and place it in the water bath. Measure the diameter of the balloon when inflated and calculate the volume of gas using the formula for the volume of a sphere ($4/3\pi r^3$).

NOTES

Investigate

1. Use a can of your favorite carbonated soft drink to explore the quantity of gas that can be dissolved in a liquid under pressure.
   a) How many milliliters (mL) of liquid are in the can of soda?
   b) Predict how many milliliters of gas (carbon dioxide) a can of soda contains. Record and explain your prediction.
2. Obtain these materials: heat source, 1-liter Pyrex® beaker, water, rubber tubing (about 50 cm), smaller beaker or bottle, plastic container (shoebox size), modeling clay, safety goggles.
3. Devise a way to use the materials to measure the gas that escapes from the can of soda. Note: You will need to heat the soda after you have opened it. To do this safely, put the can in a water bath (container of water) and heat the water bath.
   a) Draw a picture of how you will set up your materials.
   b) Write down the procedures you will follow. Include the safety precautions you will take.
4. After your teacher has approved your design, set up your materials. Run your experiment.
   a) Record your results.
   b) How do your results compare to your prediction?
   c) Describe anything that might have affected your results.

Plan your activity carefully in detail to avoid potential hazards.

Investigate

The purpose of this investigation is for students to develop a way to measure the amount of dissolved gas in a can of soda.

Safety precautions include the following:

- Check all students' designs before allowing them to proceed with their investigation.
- Make sure that students are aware of all standard safety precautions when working with glassware and heat sources.
- Make sure that students observe the following: (1) The students should not completely seal the top of the soda can with modeling clay; it is not safe to heat a closed container. The modeling clay should be used only to secure the rubber tubing in place. (2) The students should not put the rubber tubing all the way to the bottom of the soda can; the tubing could melt if too close to the heat source. (3) The students should not turn the heat all the way up—the soda should be warmed, not boiled.

The basic design for determining the amount of dissolved gas in a can of soda consists of two parts: the source of dissolved gas, and the system for collecting the gas. The source of dissolved gas is a can of soda that is heated inside a water bath. The can of soda is placed into a 1-L Pyrex beaker that is partially filled with water, then placed on a heat source. The collection device consists of a length of rubber tubing that runs from the soda can and into a beaker that is inverted within a container of water and filled with water. As gas from the can of soda comes out of solution, it enters the rubber tubing and travels to the collection device. The tubing should be inserted into the inverted beaker under water so that as bubbles of gas come out of the tube, they displace the water trapped in the smaller beaker. For obvious reasons, the last thing that should happen before the start of the experiment is opening the soda can and inserting the rubber tubing.

You can demonstrate the collection system as follows: Fill a container of water, push a beaker down into it (allowing water to fill the beaker), and run a length of rubber tubing into the inverted beaker. Blow into the rubber tubing to show students how air displaces water in the inverted beaker. Ask them how they can determine the volume of the gas that has entered the beaker (answer: read the scale on the side of the beaker while it is under water).

Exact results are not imperative in this investigation. Emphasize safety, proper experimental design and recording of data, and the general concept over exact measurement.

Assessment Tool

***EarthComm* Notebook Entry-Evaluation Sheet**
The ***EarthComm* Notebook Entry-Evaluation Sheet** will help you to structure an assessment of science process skills.

Reflecting on the Activity and the Challenge

You worked with a material that resembled volcanic products. When you opened the can of soda, you lowered the pressure inside the can. This allowed carbon dioxide (the dissolved gas) to come out of solution. Dissolved gases emerge from the Earth's interior in much the same way.

Digging Deeper

VOLCANOES AND THE ATMOSPHERE

Volcanic Gases

Gases that escape in greatest abundance from volcanoes are water vapor, carbon dioxide, hydrogen chloride, and nitrogen. These and certain other gases have played an important role in the Earth system throughout the long span of geologic time, and they continue to do so at the present time.

The atmosphere of the Earth early in its history contained abundant carbon dioxide but no oxygen. After primitive algae made their appearance partway through Earth history, the carbon dioxide emitted by volcanoes was gradually converted to oxygen by photosynthesis.

Carbon dioxide is more dense than air and sometimes accumulates in a low spot near a volcanic eruption. High concentrations of carbon dioxide are hazardous, because they cause people and animals to suffocate.

Water vapor is an essential component of the Earth system. It is especially important for human communities, because it sustains life. When you think of the water cycle, do you think of volcanoes? Volcanoes release abundant water vapor. Most of the Earth's surface water seems to have been released from the Earth's interior by volcanoes throughout the Earth's history.

Some volcanoes emit sulfur dioxide gas in great abundance. Sulfur dioxide combines with water vapor and oxygen to form sulfuric acid. The sulfuric acid is washed out of the atmosphere by rain, over large areas downwind of the eruption. Rain that contains sulfuric acid, and certain other acids as well, is called acid rain. It is produced not only by volcanoes but also by power plants that burn coal containing sulfur. Acid rain damages plants both on land and in lakes.

Volcanoes and Climate Change

Volcanoes illustrate the complexity of Earth's systems, because the gases from volcanic eruptions can contribute both to global cooling and to global warming.

Reflecting on the Activity and the Challenge

The brief passage here connects the experiment to what happens when a volcano erupts. It is worth pointing out to students that carbon dioxide is a colorless, odorless gas, which makes it particularly hazardous to humans and other animals.

Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** (page 43) can be provided as a homework assignment.

How do volcanoes affect climate? If the Earth system were simple, the task of answering that question might be easy. Suppose that volcanic activity is the independent variable. This is the variable that, when changed, causes a change in something else (the dependent variable). In a simple model, climate would be the dependent variable. You could plot volcanic activity over time and compare it to temperature (an aspect of climate that can be measured) over time. Temperature changes that follow volcanic events would allow you to make inferences about the effects of eruptions on climate. However, the Earth system is complex. Records of climate and volcanic activity are imperfect. Some volcanic products should warm the atmosphere (carbon dioxide, a greenhouse gas). Others should cool the climate (dust, which reduces sunlight). The task of understanding climate change is obviously very complicated. The evidence at hand, however, suggests that major volcanic eruptions can lower the average temperature of the Earth's surface by a few tenths of a degree Celsius for as long as a few years.

It is often thought that volcanic eruptions increase or cause rainfall near or downwind of the eruption. Volcanoes put dust into the air. Water droplets in clouds form around small dust particles. Eruptions can also heat the local atmosphere. This should increase convection, or circulation, of the atmosphere. Finally, some volcanic eruptions release great quantities of water vapor needed to form clouds and rain. However, a number of studies show that an increase in rainfall is rare after an eruption. The major eruption of Krakatoa in 1883 did not increase rainfall, and it occurred during the wet (monsoon) season. It seems that conditions in the atmosphere near a volcanic eruption have to be just right for rainfall to increase just because of the eruption.

Enormous quantities of sulfur dioxide gas from a volcanic eruption can be put all the way into the stratosphere (the upper layer of the atmosphere, above the weather). It then slowly reacts with water to form tiny droplets of sulfuric acid, less than a thousandth of a millimeter in diameter. Unlike in the troposphere (the lowest layer of the atmosphere), these sulfur dioxide droplets are not affected by the water cycle. They stay suspended in the stratosphere for as long as a few years. The sulfur dioxide droplets, as well as the large quantities of very fine volcanic ash particles that also reach the stratosphere during major volcanic eruptions, reflect sunlight and are thought to cause the global cooling that is often observed for a few years after a major volcanic eruption. For example, following the eruption of Tambora in Indonesia in 1815, many areas in the United States and Canada had unusually cold summer weather. In New England, 1815 was called the "year without a summer."

Check Your Understanding

1. What gases escape from volcanoes?
2. Why does the emission of carbon dioxide pose a threat near volcanic eruptions?
3. How are volcanoes connected to the water cycle?
4. a) How is acid rain formed?
   b) Are volcanoes the only source of acid rain?
5. Do volcanic eruptions increase or decrease the temperature of the Earth? Explain your answer.

Check Your Understanding

1. Volcanoes release carbon dioxide, water vapor, hydrogen chloride, and nitrogen in the greatest abundance, as well as many other gases, although usually in lesser abundance.

2. Carbon dioxide is more dense than air, so it tends to flow downslope underneath the surrounding atmosphere. If it accumulates in topographic depressions around a volcano, humans and animals can suffocate.

3. Volcanoes are connected to the water cycle because they absorb and release water. For example, they release water vapor into the atmosphere when they erupt, and their deposited ash absorbs water that falls onto or runs over the surface.

4. a) Sulfur dioxide gas released from volcanoes combines with oxygen and water in the atmosphere to form sulfuric acid, that becomes dissolved in rainwater to fall as acid rain.

   b) No. The burning of coal and oil, which contain small and variable amounts of sulfur-bearing compounds to generate electricity, also releases sulfur-containing gases into the atmosphere.

5. Answers will vary. Cooling results from the reduction in incoming solar radiation that reaches the lower atmosphere and the Earth's surface, for as long as the volcanic products remain in the atmosphere. On longer time scales, the release of greenhouse gases into the atmosphere can contribute to global warming.

Assessment Tool

Check Your Understanding Notebook Entry-Evaluation Sheet
This evaluation sheet is used to help you evaluate the extent to which students understand the key concepts explored in the activity and explained in the **Digging Deeper** reading section.

Understanding and Applying What You Have Learned

1. Think about the air you are breathing. How much of it came from some distant volcano?
2. If a volcano erupted huge amounts of ash, would you expect global temperatures to go up or down? Why?
3. If warm air rises, why would hot gases from a volcano be a threat to people in the valley below? (Hint: think about volume's effect in your work with the lava flow lab.)
4. If a system consists of many parts that affect each other, how are volcanoes part of systems on Earth?

Preparing for the Chapter Challenge

Use the information in this activity to argue that volcanoes have affected virtually every community. Consider ways in which you can include these arguments in your story line.

Inquiring Further

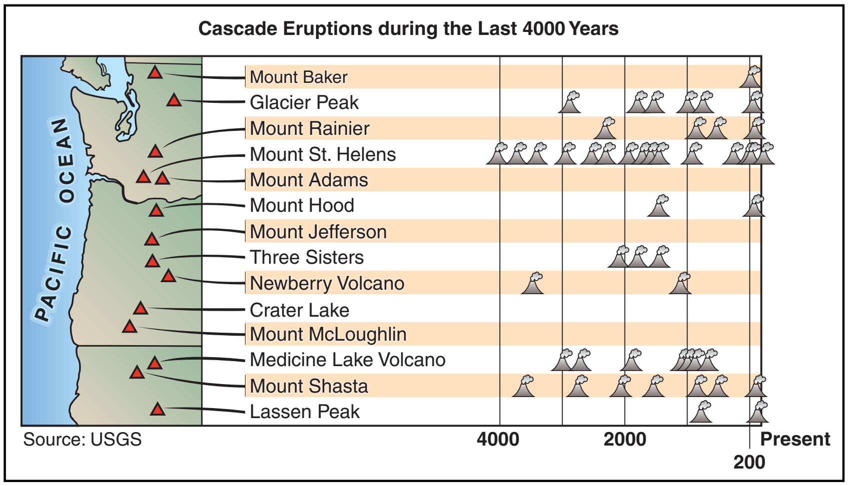
1. **Cascades eruptions**

   Examine the figure showing the eruptions of Cascade volcanoes during the last 4000 years.

   a) Which volcano has been most active? Which volcano has been least active? Explain.

   b) What three volcanoes do you think are most likely to erupt next?

   c) Visit the AGI *EarthComm* web site for a link to the USGS Cascades Volcano Observatory web site. Find out about their monitoring efforts.



Understanding and Applying What You Have Learned

1. The word "distant" in this question rules out breathing gases that are delivered directly to you by local winds from a nearby volcano. The mixing time of the Earth's atmosphere (the time it would take for a parcel of gas released at some point to be mixed thoroughly) is several weeks within the same Hemisphere, Northern or Southern, and considerably longer for worldwide mixing.

If a distant volcano has been erupting into the atmosphere anywhere on Earth in recent weeks or months (and that is just about always true), then you are breathing air that contains some very small percentage of gases, mostly in trace amounts, that have recently come out of a volcano.

2. If such an eruption occurred it would probably cause global cooling, although the relatively new presence of chloro-fluorocarbons (CFCs) in the stratosphere means that sulfur dioxide from volcanoes can now contribute to global warming. Students' responses should reflect a consideration for the relationship between ash, volcanic gases, and the amount of solar energy entering the Earth system.

3. Much of the gas does indeed rise up into the atmosphere and become mixed and dispersed there. Two effects, however, combine to cause some of the volcanic gas to remain near the ground: (1) volcanic gases are typically rich in components like carbon dioxide that are denser than air; and (2) gases that are charged with fine suspended ash have a higher bulk density than gas without suspended ash particles; this effect can be greater than the effect of temperature decreasing the density of the gas.

4. Answers will vary, but should cite evidence from activities and readings about the relationship between volcanoes and the hydrosphere and atmosphere.

Preparing for the Chapter Challenge

Students may have begun the chapter thinking of volcanoes as having largely only local effects on people and communities. This activity should have helped students to better understand how volcanoes are part of the Earth system. Encourage students to return to the statement of the **Chapter Challenge** and the description of the Earth systems.

Review the **Assessment Criteria** within your scoring rubric for the **Chapter Challenge**, pointing out that the investigation provides an excellent opportunity for students to demonstrate what they have learned about how volcanoes change Earth systems.

Inquiring Further

1. Cascades eruptions

This investigation allows students to explore the volcanoes that are of particular concern in the western United States. The *EarthComm* web site will help students to explore the Cascades Volcano Observatory web site. Alternatively, you may wish to bring in material from the site that you have downloaded and printed out for them to examine. The Cascades Observatory makes an excellent introduction to the final activity of the chapter on monitoring volcanoes.

a) Mt. St. Helens has been the most active; it has had 15 eruptions in the last 4000 years. In the last 4000 years, Mount Baker has only had one eruption, so it is the least active. Mount Adams, Mount Jefferson, Crater Lake, and Mount McLoughlin have been dormant for the past 4000 years, so some students may argue that they have been the least active.

b) This question really depends upon student interpretation. Students could argue that Glacier Peak has erupted twice every 500 years or so and just erupted recently, so it will erupt again soon. Newberry Volcano erupted at an interval of about 1500 years, and if it maintains this pattern, will erupt soon. Mount Shasta appears to erupt with a regular frequency, and could therefore erupt soon.