Volcanoes and Global Warming

Key Concepts:

- Carbon dioxide
- Sulfur dioxide
- Sulfate aerosols
- Greenhouse effect

WHAT YOU WILL LEARN

1. You will identify materials ejected by volcanic activity.
2. You will name the volcanic gases that act as greenhouse gases.
3. You will describe how sulfur aerosols act to cool the atmosphere.
4. You will compare and contrast the effect of human activity and volcanic activity on the temperature of the atmosphere. You will then transform the data into a graphic form.

Engage Your Thinking

Are volcanoes a source of atmospheric **carbon dioxide**? This question is a point of controversy concerning the **greenhouse effect** and its potential impact on global warming. In this activity you will learn how volcanic eruptions contribute to atmospheric carbon dioxide, the greenhouse effect, as well as global temperatures. When a volcano erupts, it ejects many different types of material into the air including a variety of gases and ash (small particles of dust). Among these gases are water vapor and carbon dioxide. Both are greenhouse gases and can contribute to the greenhouse effect. Carbon dioxide levels in the atmosphere have been increasing; now scientists are studying whether volcanoes are playing a significant role in the greenhouse effect.

1. Which contributes more carbon dioxide per year to the atmosphere: volcanic eruptions or human activity?

2. Does a volcanic eruption cause a warming or cooling effect?

Explore and Explain

Large volcanic eruptions deposit **water vapor** (H_2O), carbon dioxide (CO_2), **sulfur dioxide** (SO_2), and other gases into the environment. Volcanoes can also put great amounts of ash (small particles of dust) into the air. As you have learned, carbon dioxide and water vapor are greenhouse gases and can contribute to global warming. Water can combine with other volcanic gases to form hydrochloric acid (HCl) and hydrofluoric acid (HF) to fall as acid rain. Volcanoes also emit sulfur dioxide, which converts to a fine mist of particulates that migrate high into the atmosphere. These sulfur dioxide particulates are called **sulfate aerosols** and they reflect sunlight into space. Sulfate aerosols encourage the formation of high clouds which also reflects sunlight into space. Therefore, aerosols and clouds reduce the amount of warming and cause the atmosphere to cool. Sulfate aerosols tend to stay in the upper atmosphere for long periods of time (months or

even years) until they finally are brought to earth in the form of sulfuric acid. The volcanic ash in the atmosphere also blocks sunlight from reaching the surface of the earth, causing the air to cool. (The ash eventually falls to the ground.)

3. Which greenhouse gases are added to the atmosphere during a volcanic eruption?

4. How does a volcanic eruption cause the atmosphere to cool?

Other factors must be considered in the study of volcanic eruptions and their impact on the atmosphere. All volcanoes are not the same. The type of eruption is dependent upon the circumstances that cause the volcanic activity. Volcanoes created by hotspots in the ocean are rarely explosive and do not eject much ash. Eruptions taking place at tectonic plate boundaries, however, can be very explosive with much ash. Also, the types and amounts of gases ejected by each type of volcano differ. Table 1 shows gases ejected by three different volcanoes situated at three different geographic locations. Make a bar graph that shows the amount of H_2O, CO_2, and SO_2 emitted by the three different volcanoes. You will need graph paper.

Volcano Tectonic Style Temperature	**Kilauea Summit** Hot Spot 1170°C	**Erta` Ale** Divergent Plate 1130°C	**Momotombo** Convergent Plate 820°C
H_20	**37.1 %**	**77.2 %**	**97.1 %**
$C0_2$	**48.9 %**	**11.3%**	**1.44%**
$S0_2$	**11.8%**	**8.34%**	**0.50%**

Table 1. Examples of volcanic gas compositions
(Source: USGS)

5. In general, volcanoes eject which gas the most?

6. Which volcano ejected the greatest percentage of carbon dioxide?

Many people argue that volcanic eruptions are a major cause of carbon dioxide levels in our atmosphere. In reality, volcanic eruptions contribute very little to the atmosphere's carbon dioxide levels. Below are the USGS carbon dioxide emission estimates for volcanic and human activity (Table 2).

Table 2. Yearly average carbon dioxide emissions

From volcanoes:	145 – 225 million tons of CO_2
From human activity:	30 billion tons of CO_2

Let's express the volcano amount as about 200,000,000 or 2.0 X 10^8 tons. The human activity amount is 30,000,000,000 or 3.0 X 10^{10} tons.

Imagine making a bar graph to compare the carbon dioxide contribution of volcanoes and human activities (You will not actually make the graph.). First, using a scale on which one centimeter represents 1.0 X 10^8 tons, your bar graph would represent the carbon dioxide contributed by volcanoes with a bar 2 centimeters high. Volcanoes emit 2.0 X 10^8 tons of CO_2 per year, which gives you a bar that is 2 centimeter high.

7. Calculate the height of the bar representing carbon dioxide from human activity.

8. How important are volcanoes in adding carbon dioxide to the atmosphere?

Extend Your Thinking

Mount Pinatubo is a volcano that lies near a divergent plate boundary in the Philippines. In June of 1991, Mount Pinatubo violently erupted, and this is now on record as the second largest volcanic eruption of the Twentieth Century. The eruption had ten times the explosive power of the 1980 eruption of Mount St.

Helens in the state of Washington. Within two hours of the major Pinatubo eruption, gases and ash had reached high into the atmosphere. During the following two weeks, the sulfate aerosols created by the blast circled the globe. At the end of a year, the entire atmosphere of the earth was filled with a layer of sulfate aerosols ejected from the eruption.

The sulfur aerosols created by the Pinatubo blast reflected solar energy (heat and light) into space and decreased temperatures around the world in 1992 and 1993. In spite of rising amounts of greenhouse gases and the presence of an El Niño event (factors that should warm the atmosphere), the sulfate aerosols reduced global temperatures in 1992 and 1993 by about 0.4 to 0.5ºC: a global cooling effect. The United States experienced its third coldest summer in seventy-seven years.

The 1815 eruption of theTambora Volcano in Indonesia created an even larger global cooling effect. Global temperatures were lowered by as much as 3ºC. The year 1816 was known as the year without summer in many parts of Europe and North America. Many Midwestern states experienced snowfall in June and frost in July.

9. What is the effect of the sulfate aerosols formed by volcanoes on global temperatures?

Apply What You Have Learned

Draw an erupting volcano. In your drawing, draw and label the materials that are ejected by the volcano. Under your drawing, explain the effect of each material on the temperature of the atmosphere.

Reflect on What You Have Learned

10. Which contributes more carbon dioxide per year to the atmosphere: volcanic eruptions or human activity?

11. Does a volcanic eruption cause a warming or cooling effect?

12. What is the major cause of cooling after a volcanic eruption?

13. Please explain how your ideas and thinking about volcanoes and global warming have changed.

