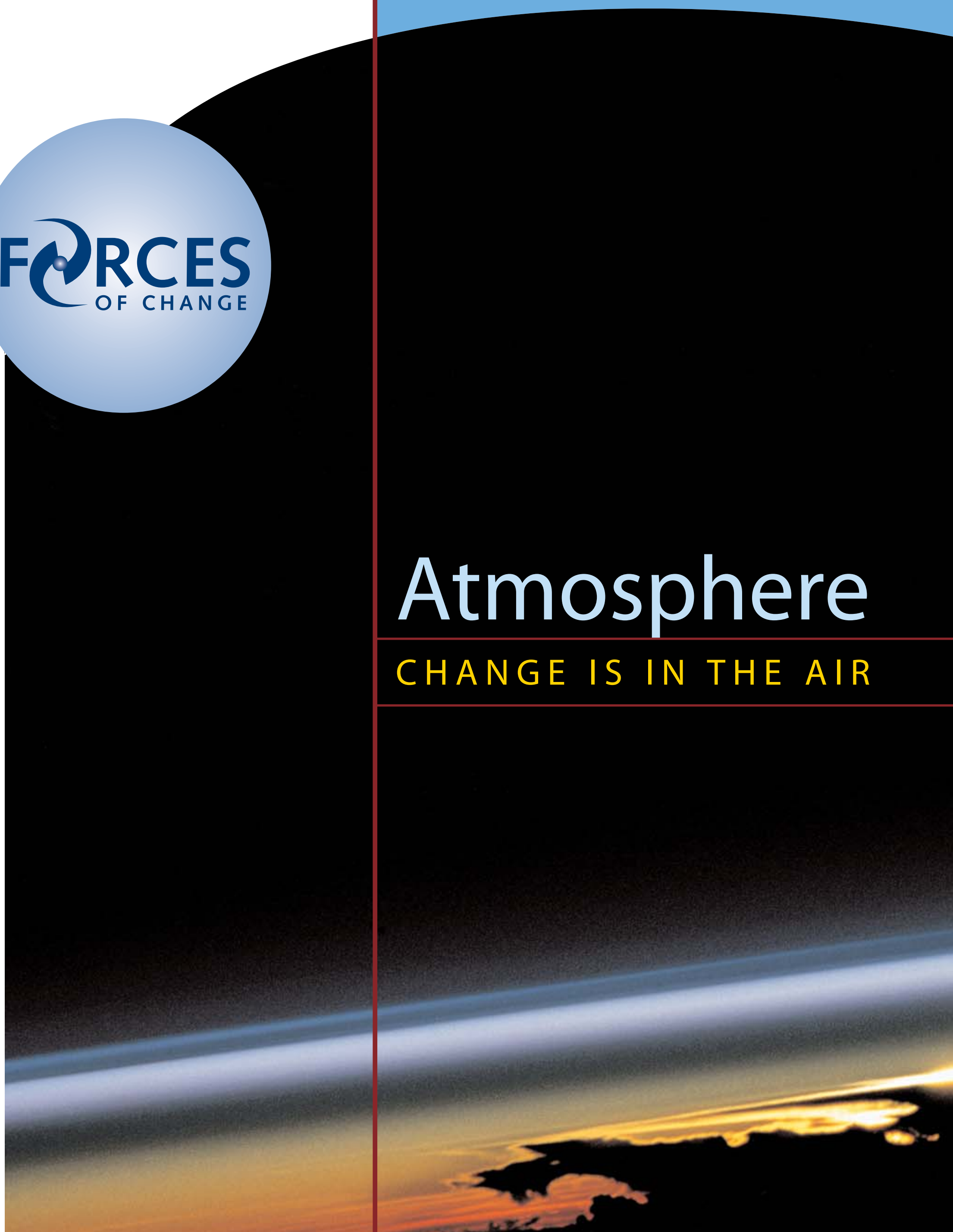
Activity 3

Zapped! The Atmosphere Reacts

FORCES OF CHANGE



Atmosphere

CHANGE IS IN THE AIR

Smithsonian
National Museum of Natural History

ACTIVITY 3

Zapped! The Atmosphere Reacts

Overview

At any given moment, dozens of chemical reactions are taking place in the atmosphere. Some of the most common reactions involve molecules of oxygen or ozone, both of which contain oxygen atoms and are highly reactive. Breathing ozone can damage the lungs. Schoenbein paper tests for the presence of ozone in the air through a reaction between ozone and potassium iodide that produces a purple color. By making their own Schoenbein paper, students will test for ozone and the conditions that lead to its formation.

Suggested Grade Level

7–9

National Standards Alignment

National Science Education Standards
Science As Inquiry, Grades 5 to 8, Content Standard A: As a result of activities in grades 5–8, all students should develop abilities to do scientific inquiry and understandings about scientific inquiry.

Design and conduct a scientific investigation: Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables.

Science in Personal and Social Perspectives: Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air.

Benchmarks for Science Literacy, Project 2061, AAAS
Scientific Inquiry, all grades, pgs. 9–13.

Time

Two class periods (40–50 minutes) and overnight/8-hour exposure of Schoenbein Paper

Materials

- Potassium iodide (5g (one teaspoon) will be plenty)
- Distilled water (must use distilled water)
- Spray bottle filled with distilled water (must use distilled water)
- Filter paper
- Heat source (preferably a hot plate)
- Corn starch

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Materials (continued)

- Glass stirring rod (do not use metal)
- Small paint brush
- 250 ml beaker
- Glass Pyrex plate
- Hot pad or mitt for removing the beaker from the heat source
- 8-1/2 x 11-inch paper for drying filter paper
- Map of city or school building
- Air tight containers
- Scissors
- Sealable plastic bags

Vocabulary

OZONE — highly reactive gas containing three atoms of oxygen

Schoenbein paper—paper saturated with potassium iodide that can show the presence of ozone in the air

TROPOSPHERE — area of the atmosphere from the ground up to 14.5 km (9 mi) above Earth

STRATOSPHERE — area of the atmosphere between 14.5 to 50 km (9 to 31 mi) above Earth

ATMOSPHERE — the invisible blanket of air that surrounds Earth and consists primarily of nitrogen and oxygen

QUALITATIVE COMPARISON — comparison of results relative to each other without assigning numbers or quantities

RELATIVE HUMIDITY (RH) — percent of water in the air compared to the maximum amount (100 percent) the air could hold

OBJECTIVES

Students will be able to:

1. Identify the layers of the atmosphere.
2. Define ozone and locate where it can be found within the layers of the atmosphere.
3. Explain that the Schoenbein paper detects ozone by an oxidation reaction wit potassium iodide.
4. Demonstrate that by using Schoenbein paper they can determine variations in the amount of ozone present in the troposphere from day to day and from place to place.
5. Draw conclusions about ozone levels of the air based on test results.

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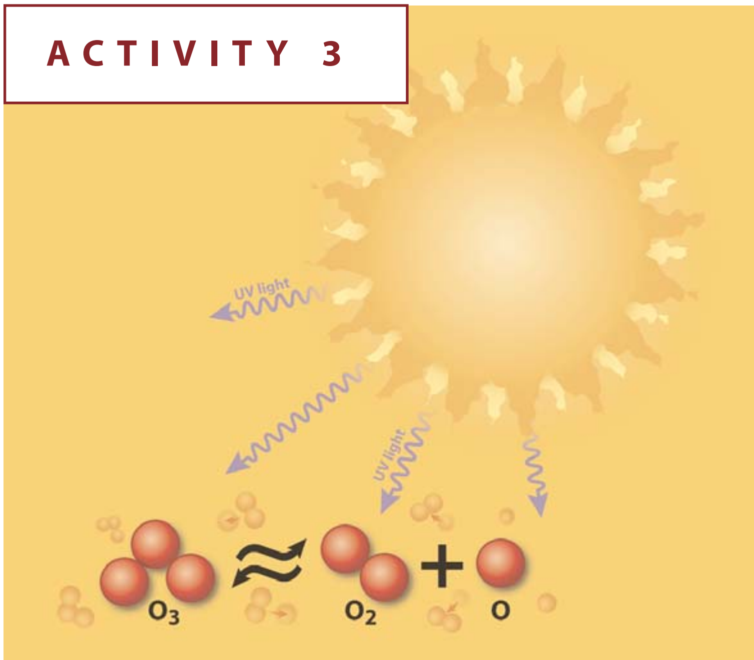

Graphic by The M Factory © Smithsonian Institution

Background

Oxygen, a gas that we inhale with every breath, is essential to life on Earth. But as a chemical, oxygen is reactive. That property makes it life-sustaining and also a source of pollution.

A single molecule of oxygen (O_2) contains two oxygen atoms. But add another oxygen atom, and you have ozone (O_3). In the stratosphere, ozone protects us, absorbing much of the sun's harmful ultraviolet radiation. But carried in the air we breathe at ground level (the troposphere), ozone is a poison that burns and corrodes living and non-living things.

Small amounts of ozone develop naturally, especially during lightning storms, but spew industrial chemicals and automobile exhausts into the atmosphere, cook them with heat and sunlight, and ozone levels can rise dangerously high. Ozone is the main component of "photochemical smog."

Christian Friedrich Schoenbein discovered ozone in 1839 while he was a professor at the University of Basel in Switzerland. He took advantage of ozone's reactivity to develop a way to measure the presence of ozone and demonstrate that it occurs in the atmosphere. Schoenbein used a mixture of starch, potassium iodide (KI), and water spread on filter paper. The paper, called Schoenbein paper, changes color in the presence of ozone. Ozone in the air causes iodide (KI) to oxidize into iodine (I2). The iodine reacts with the starch, staining the paper purple. The intensity of the purple color depends on the amount of ozone present in the air. The darker the color, the more ozone present.

The reactions involved are $2KI + O_3 + H_2O \longrightarrow 2KOH + O_2 + I_2$

I_2 + starch —> purple color

NOTES: this activity works best in areas of low humidity and high ambient ozone concentrations. In some parts of the country, this activity may not be very conclusive. Because relative humidity affects results, Schoenbein paper should not be left outside during periods of high humidity. The xerographic process in most copy machines uses electrostatic charging of a cylinder. The accompanying ionization creates ozone in adjacent air, so a room containing a copy machine makes a good location for this experiment.

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Activity

Schoenbein Paper Preparation (For safety, you may want to prepare the paper as a demonstration. Students should wear goggles.)

1. Place 100 ml of distilled water in a 250 ml beaker.
2. Add 6 g (1-1/4 teaspoon) of cornstarch.
3. Heat and stir mixture until it gels. It will thicken and become somewhat translucent.
4. Remove the beaker from the heat, add 1 g (1/4 teaspoon) of potassium iodide, and stir well. Cool the solution before applying it to the filter paper.
5. Lay a piece of filter paper on a glass plate or hold it in the air, and carefully brush the paste onto the filter paper. Turn the filter paper over and do the same on the other side. Try to apply the paste as uniformly as possible.
6. Wash your hands after applying the potassium iodide mixture. (Although potassium iodide is not toxic, it can cause mild skin irritation.)
7. Set the paper out of direct sunlight and allow it to dry. A low-temperature drying oven works well if available.
8. Cut the filter paper into 2.5-cm (one-inch) wide strips.
9. To store the paper, place the strips in a sealable plastic bag or glass jar out of direct sunlight.

Testing Procedure

1. Each student should be given at least two strips to test.
2. Spray a strip of test paper with distilled water and hang it at a data collection site **out of direct sunlight**. Make sure the strip can hang freely.
3. Expose the paper for approximately eight hours. Note the exact location where you hung each strip. Be sure to include as many details as possible, such as the presence of nearby roads or busy streets, buildings, forests, type of location, etc.
4. After exposure, seal the strip in an airtight container if the results will not be recorded immediately.
5. To observe and record test results, spray the paper with distilled water. Observe and record the paper color.

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Hazy skies over Los Angeles, California on a typical spring day

Photo © Galen Rowell/CORBIS

Qualitatively Determine Ozone Level

1. Have students compare their test strips. This is a qualitative comparison. While you cannot assign numbers to this test, you can make relative comparisons. Strips that show little or no change were in places with the lowest ozone concentrations. Strips that have a lavender appearance were exposed to more ozone and, finally, those that look dark purple had high ozone exposures.

Questions

1. What change in the test paper, if any, did you observe? (The paper will vary in color depending on the amount of the oxidation. The color of the paper may not be uniform.)

2. Compare your test paper to other students'. Do all the test papers appear the same? (The individual test papers will vary depending on the amount of oxidants at various sites. For example, sites near highways will show greater color change due to oxidants from car exhaust and nitrous oxides in heavy traffic areas.)

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Questions (continued)

3. Was the relative humidity for your test day high or low? (You can find out by calling the local weather service or listening to the weather report on radio, television, or the Internet (www.weatherchannel.com). The results of individual test papers will vary depending on the specific relative humidity of the site. Sites near lakes or streams may show greater change.

4. Why do you think the various test papers did not all appear the same? (Student answers will vary. Tropospheric ozone levels vary widely due to the type and number of sources of ozone. Students measuring ozone in their homes may report little color change of the paper, but if they live on a busy street, a measurement near the curb will register greater color change. Humidity and oxidants are present in varying levels depending on the time of day, the weather, the season, etc.)

5. Based on the data, do you think this method is a good way to measure ozone in the troposphere? Why or why not? (Some students will point out the difficulty in interpreting the color accurately, while others will note the differences in how the paper was produced from group to group. It is important to stress that this is a good method for measuring relative amounts of ozone.)

Observations

1. Was there any variation in ozone levels on the map?
2. Where on the map were the concentrations the highest? The lowest?

Conclusions

1. Looking at the area of highest concentration, does there appear to be any obvious explanation for the variation?
2. Why do you think there were ozone level variations?

Learning More

The Aura satellite was launched by NASA in 2004 to monitor air quality, including levels of tropospheric ozone, around the world. To learn more about how a satellite orbiting 705 km (438 mi) above Earth can measure ozone at ground level, visit the NASA Aura website at http://www.nasa.gov/vision/earth/lookingatearth/aura_first.html.
For multimedia presentations visit http://www.nasa.gov/mission_pages/aura/multimedia/index.html.

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Learning More (continued)

The Environmental Protection Agency (EPA) created the Air Quality Index to report the amounts of five pollutants in the air. Code Green means air quality is good. Code Red means that ground-level ozone levels are so high that children, older people, and people with chronic lung conditions should stay indoors. On Code Red days, it's smart to postpone buying gasoline or pouring gasoline into your lawnmower until after sundown. That's because ozone forms when hydrocarbons like gasoline fumes mingle with sunlight and heat. For more on the Air Quality Index visit the EPA at http://airnow.gov/index.cfm?action=airnow.main

Extensions

1. Using a city or county map of your area, have students place sticky dots corresponding to the color of the Schoenbein paper from the location for which they collected data. Have students initial their dot.
2. Compare data your students collect with those from a local monitoring station (need URL or reference). Also, if possible, get information about the wind direction during your study.
3. Contact your local Air Quality Control Board (also known as Air Pollution Control Board-check with your local environmental protection authority) and request data for your test week. Do your readings parallel those from the control board?
4. It is always a good idea to get as many readings as possible. Incorporate other grade levels and other schools (see www.globe.gov and look under Student Investigations for more data about ozone). Compare data from students in different cities and states. Do you see correlations or patterns?

References

http://www.nasa.gov/vision/earth/lookingatearth/aura__first.htmlhttp://www.nasa.gov/mission__pages/aura/multimedia/index.htmlwww.globe.gov

http://airnow.gov/index.cfm?action=airnow.mainhttp://liftoff.msfc.nasa.gov/academy/space/atmosphere.html