Experiment 1:

Testing for Ground-Level Ozone

Difficulty: Easy to Moderate

Background

The Earth's upper ozone layer acts like sunscreen, or a shield that protects organisms on Earth from dangerous ultraviolet radiation (UV rays) given off by the Sun. When certain chemicals are continually released into the atmosphere, their reaction with the upper ozone layer is destructive. For example, chlorofluorocarbons (CFCs), used during the 1960s and 70s as propellants in some aerosol products, caused significant damage to the Earth's upper ozone layer, reducing protection on Earth from harmful UV rays.

The Earth's upper ozone layer, located in the stratosphere, is often confused with the Earth's ground-level ozone layer, contained in the troposphere. High concentration of ozone in the stratosphere is good because it increases protection from the Sun's UV rays. However, ozone in the troposphere is often called "bad ozone" because it is a component of "smog." Vehicle exhaust, industrial emissions, gasoline vapors and chemical solvents react when mixed with strong sunlight and bad weather to create "bad ozone," which pollutes the air. For humans, this leads to respiratory health problems including bronchitis, heart disease, emphysema, and asthmas. In addition, high concentrations of "bad ozone" damage plant life by interfering with the ability of plants to produce and store food, making them more susceptible to disease, insects, pollutants and harsh weather.

In the 1970s, consumer aerosol products became associated with the "hole in the ozone layer" because they used CFCs as propellants. Because CFCs damage the Earth's upper ozone layer, they were banned as propellants in the U.S. in 1978. Most countries around the world soon followed the U.S. and also banned the use of CFCs as propellants in most consumer aerosol products. Recent studies have shown that the upper ozone layer has made significant progress in repairing itself as a result of regulation.

Ozone gas was discovered in 1839 by Christian Schoenbein. He demonstrated that ozone is a natural component of the lower atmosphere (the troposphere) and developed a way to measure the amount of ozone using a mixture of starch, potassium iodide and water spread on filter paper. Called "Schoenbein paper," it changes color when ozone is present because ozone causes iodide to oxidize into iodine (I_2) in the reaction:

$$2KI + O_3 + H_2O - 2KOH + O_2 + I_2$$

The iodine reacts with the starch, staining the paper a shade of purple. The intensity of the blue/purple color measures the amount of ozone present in the air: the darker the color, the more ozone that is present.

[Note: In areas of high humidity, this activity may not be conclusive.]

Learning Goals

1. The student will understand the presence of ozone gas in our atmosphere.
2. The student will be able to use Schoenbein paper to demonstrate variations in the amount of ozone present in the troposphere, and to discover that the amount of ozone can vary from day to day and from place to place.
3. The student will be able to explain Schoenbein paper detection of ozone as an oxidation reaction caused by the ozone in the surrounding air.
4. The student will be able to draw conclusions about cause and effect of varying ozone levels in the air based on test results.

Materials for Making Schoenbein Paper

- Potassium iodide (available from a science laboratory or science supply catalog)
- Distilled water
- Spray bottle filled with distilled water
- Filter paper (coffee filter paper may be used)
- Heat source (preferably an electric hot plate or an electric range)
- Corn starch
- Glass (not metal) stirring rod
- Small brush, such as an artist's paintbrush
- 250 ml beaker or similar glass or Pyrex container
- Glass or Pyrex plate
- Clean computer paper (for drying filter paper)
- Sealable plastic storage bags or food containers
- Appropriately-detailed maps of the area to be investigated

Procedure for Preparing Schoenbein Paper

(For safety, prepare under adult supervision!)

1. In a 250 ml beaker, add approximately 1 1/4 teaspoons of corn starch to 100 ml of distilled water.

2. Heat the mixture, stirring it constantly until the mixture thickens and becomes clearer.

3. Remove the beaker from the heat source and add 1/4 teaspoon of potassium iodide, stirring well. Allow this solution to cool before proceeding to the next step.

4. With a piece of filter paper laid on the glass plate, carefully brush the paste evenly onto the filter paper. Turn the filter paper over and do the same on the other side. Immediately wash your hands of any potassium iodide solution as it may irritate sensitive skin.

5. Allow the paper to dry thoroughly. The "WARM" setting on a kitchen oven works well, but keep the Schoenbein paper out of direct sunlight at all times.

6. Cut the filter paper into 1-inch wide strips and store them in a sealable plastic storage bag out of direct
Ω ≈sunlight until used.

Procedure for Ozone Testing Using Schoenbein Paper

1. In the area to be tested for the presence of ozone, spray a strip of the test filter paper with distilled water and hang it at a data collection site out of direct sun light. Make certain the strip can hang freely.

[Note: 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.]

2. Expose the paper for approximately eight hours. Note where each strip was hung.

3. After exposure, seal the strip in an airtight container if the results will not be recorded immediately.

3. To observe and record test results, spray the paper with distilled water and observe the color.

[Note: Because relative humidity affects results, Schoenbein paper should not be left outside during periods of high humidity.]

DISCUSSION

1. Were there any changes in the color of the Schoenbein paper?

[Note: Paper color may not be uniform and will vary depending on the amount of oxidation.]

2. Might there be an explanation for the causes of color variation? For example, sites near heavy traffic areas will show greater color change due to oxidants and nitrous oxides from car exhaust.

3. Was the relative humidity for your test day high or low? The student can determine this experimentally, or consult local weather data.

[Note: Since water is a reactant in the oxidation reaction on the Schoenbein paper, humidity will affect the reaction. Sites near lakes or streams may show greater change.]

4. Besides location and humidity, what effect might time of day, wind speed, wind direction, temperature, relative humidity, clouds, rain, or even the season have on the amount of ozone present in the air? The student can collect this data experimentally, or consult local weather data.

EXTENSIONS

1. Contact a local air quality control board and request data for your test week and compare your readings to theirs. What might explain any differences? Are there any correlations? Collect daily ozone data for a week and graph the concentrations. This data can be plotted on a graph using parts per billion (ppb) on the vertical axis and the days on the horizontal axis.

2. Make a color chart of Schoenbein paper shades to ozone ppb provided by local air quality control data collected in the same site. This may assist you in inter preting your ground ozone level data.

3. Construct an ozone concentration map of your town or area by testing a variety of sites and then plotting relative ozone concentrations on a local map. *Try to identify the sources of relatively high concentrations. How does this concentration map change hourly, daily, or weekly? Is there a noticeable change on particular days of the week? Why?*