Field Testing for Ozone

EPA

JUNE 2024

Grades: 9-12
Subject: Earth Science, Chemistry
NGSS (DCI) Connections: HS-ESS3-4
Time: 2 Class Periods (1 Week Apart)

Student Objectives

- Distinguish between tropospheric and stratospheric ozone.
- Define smog.
- Discuss air quality and related health and welfare issues involving tropospheric and stratospheric ozone.
- Perform simple measurement of ozone concentration in the outdoor air.

Materials

- Potassium iodide
- Filter paper (can use coffee filters)
- Corn starch
- Glass stirring rod
- Small paint brush
- 250 mL beaker
- Heat source (preferably a hot plate)
- 9” microwaveable plate or paper plate
- Clear jar with lid or zipper lock plastic bag
- Distilled water
- Heat safe glass plate
- Full-splash safety goggles
- Aprons
- Scissors
- Schoenbein Color Scale (provided)
- Relative Humidity Schoenbein Number Chart (provided)
- Bulb psychrometer (optional)

Student Activity

This test is based on the oxidation capability of ozone. Ozone in the air will oxidize the potassium iodide on the Schoenbein paper to produce iodine. The iodine reacts with starch and produces a purple color. The exact shade of purple correlates to the amount of ozone present in the air. The two reactions involved are:

$$2KI + O_3 + H_2O \rightarrow 2KOH + O_2 + I_2$$

$$I_2 + \text{starch} \rightarrow \text{starch turns a shade of purple}$$

Background Information

The issue of ozone in the earth's atmosphere can be confusing. On one hand, we know that high above the earth's surface in the stratosphere is a layer of ozone that surrounds the planet and helps block out some of the sun’s harmful radiation. We hear reports of "holes" developing in this stratospheric ozone shield and of the harm that the increased ultraviolet radiation can cause on earth. On the other hand, we know that higher than normal concentrations of ozone in the air we breathe in the troposphere (ground-level) can be harmful to people, animals, plants, and various materials. The ozone gas in the stratosphere and troposphere is the same, the chemical O_3. In the upper atmosphere (stratosphere) it greatly benefits all life. Near the earth's surface (troposphere), it can cause problems.

Air Quality Flag PROGRAM

Adapted from the Air and Waste Management Association Environmental Resource Guide for Air Quality

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Background Info (Cont.)

The Stratospheric Ozone Layer

High in the stratosphere, a layer of ozone gas forms an important and effective protective barrier against the harmful ultraviolet (UV) radiation from the sun. In the 1970s, scientists discovered that certain human-made chemicals containing chlorine and bromine were depleting stratospheric ozone. This led to the adoption in 1987 of the Montreal Protocol, a global environmental treaty to protect the ozone layer by phasing out the production and consumption of chemicals that destroy the ozone layer. All countries have signed on to the Montreal Protocol, and the ozone layer is now expected to recover to healthy levels by mid-century. Researchers across the globe continue to study the ozone layer, the causes of its depletion, and the effects of ozone layer depletion on humans and the environment. Visit EPA's website to learn more: https://www.epa.gov/ozone-layer-protection.

Increased UV radiation at the earth's surface can lead to a greater incidence of:

- Skin cancer, eye problems such as cataracts, and immune deficiencies in humans
- Decreased crop yields, and reduced populations of microscopic sea plants and animals that are vital to the food chain

Ozone Pollution in the Troposphere

High concentrations of ozone in the ambient air that we breathe in the troposphere can cause many problems. Because ozone molecules are highly reactive, they have an effect on practically every material they contact, whether it be lung tissue, crops or other vegetation, rubber, plastic, paints, etc.

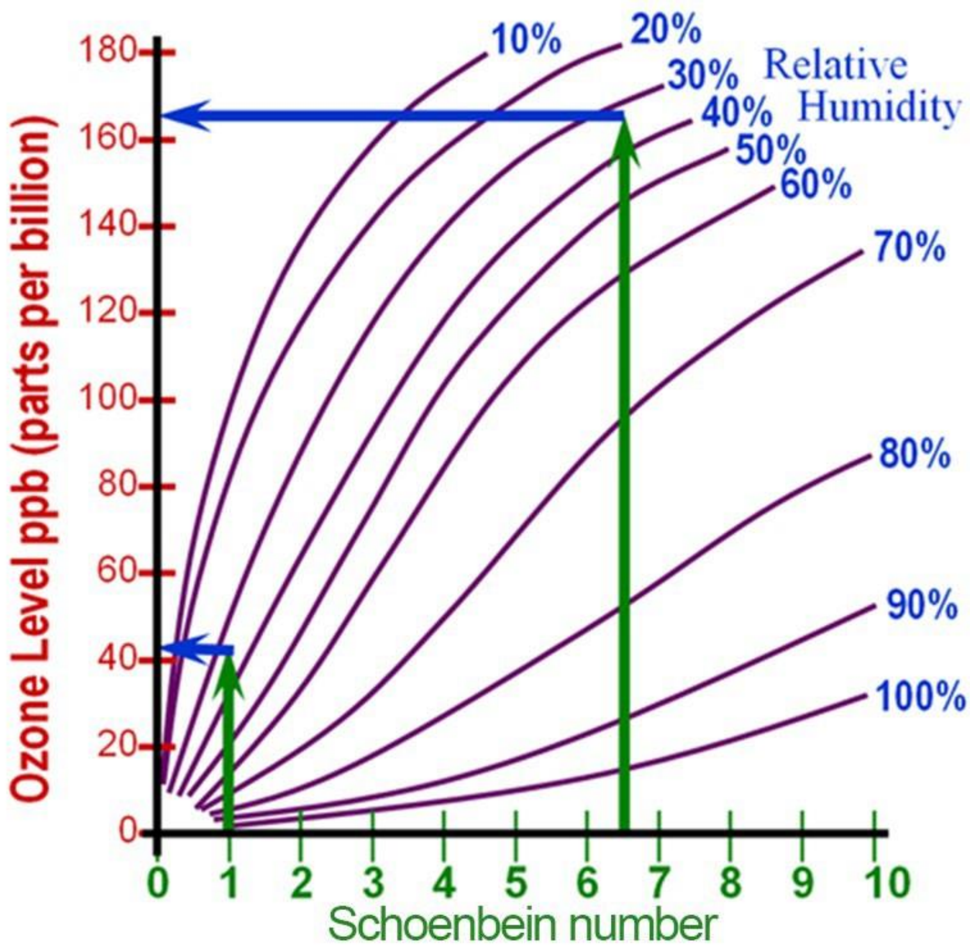
What we often refer to as "smog" is mostly ground-level ozone. The recipe for the formation of ozone in the ambient air includes volatile organic compounds (VOCs), nitrogen oxides, and sunlight. Because sunlight is a key factor, ozone pollution is generally worse during the day (particularly the afternoon) and in the summertime. Vehicle exhaust provides most of the VOCs and nitrogen oxides that form ozone, so times of increased vehicle use (such as morning and afternoon rush hours) also increase the possibility of ozone problems.

Ozone can cause eye, nose, and throat irritation, and can damage the lungs. Visit EPA's website to learn more about ozone pollution in the troposphere: https://www.epa.gov/ozone-pollution.

Field Testing for Ozone

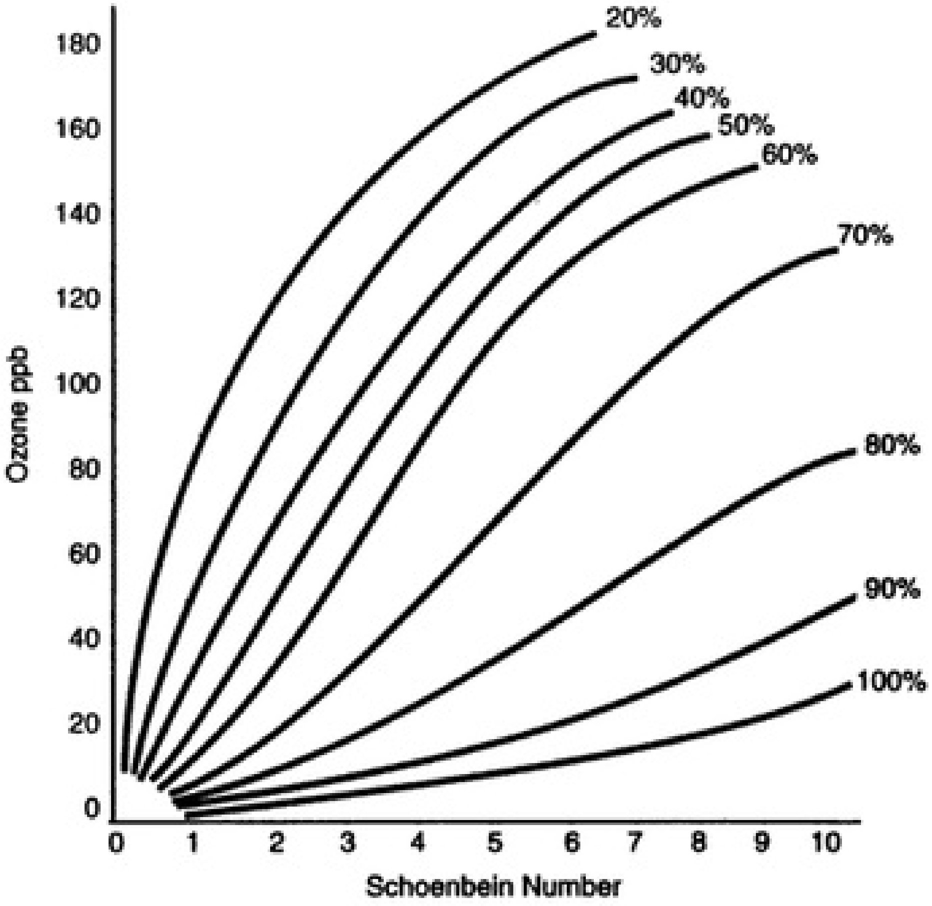
Student Directions

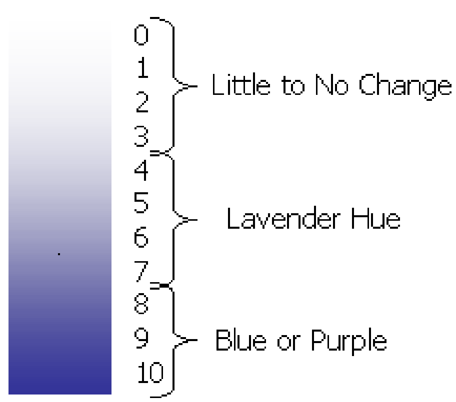
1. Place 100 mL of water in a 250 mL beaker on your heat source, then add 5 grams of corn starch.
2. Heat and stir mixture until it gels. The mixture is gelled when it thickens and becomes somewhat translucent.
3. Remove the beaker from the heat and add 1 gram of potassium iodide and stir well. Allow the solution to cool.
4. Lay a piece of filter paper (you can use coffee filters) on a glass plate and carefully brush the paste onto the filter paper. Turn the filter paper over and do the same on the other side. Apply the paste as uniformly as possible. The paper can be exposed for immediate testing at this point.
5. If you plan to test at a later time, allow the paper to dry. To save time, place the paper on a microwave-safe plate and microwave for one minute.
6. Cut the paper into small strips. To store the strips, seal them in a clear jar or zipper lock plastic bag out of direct sunlight.
7. When you are ready to sample, dip a prepared strip of test paper in distilled water and hang it at a data collection site out of direct sunlight. Make sure the strip can hang freely.
8. Expose the paper for approximately eight hours. Seal it in an airtight container if the results will not be recorded immediately.
9. To observe and record test results, dip the paper in distilled water. Observe the color and determine the Schoenbein Number using the Schoenbein color scale.
10. Determine the relative humidity of the data collection site by using a bulb psychrometer or local weather data.
11. Round the relative humidity reading to the nearest 10 percent. (Higher relative humidity makes the paper more sensitive to ozone, and a higher Schoenbein Number is observed. To correct for this, the relative humidity must be determined and figured into the calculation of the ozone concentration.)
12. Refer to the Relative Humidity Schoenbein Number Chart. Along the bottom of the chart, find the point that corresponds to the Schoenbein Number that you recorded. From that point, draw a line upward until it intersects with the curve that corresponds to your relative humidity reading. To find the ozone concentration in parts per billion, draw a perpendicular line from the Schoenbein Number/relative humidity point of intersection to the left side of the chart (see example below). *NOTE: The color of the paper may not be uniform. Determine the Schoenbein Number by the color in the area with the most noticeable change.*



Ozone Level ppb (parts per billion)
180
160
140
120
100
80
60
40
20
0
Schoenbein number
0 1 2 3 4 5 6 7 8 9 10
Relative Humidity
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Relative Humidity Schoenbein Number Chart





Field Testing for Ozone

Student Directions

1. What change in the test paper, if any, did you observe?
2. Compare your test paper to those of other students. Do all the test papers appear the same? (Individual test papers will vary depending on the amount of oxidants at that site. Be aware that false positive results can occur from nitrous oxides in heavy traffic areas.)
3. Was the relative humidity for your test day high or low? (Individual results will vary depending on the specific relative humidity of the site.)
4. Why do you think the test papers did not all appear the same?
5. Would the ozone parts per billion (ppb) be the same for a Schoenbein Number of 4 at a relative humidity of 30 percent and 70 percent? (Hint: Refer to the Relative Humidity Schoenbein Number Chart.)
6. Based on the data you collected, do you think this method is a good way to measure tropospheric ozone? Why or why not?
7. Compare data with those from a local monitoring station*. Also, if possible, get information about the wind direction during your study and determine how it affected your measurements.

*https://gispub.epa.gov/airnow/?contours=ozone

What Can Be Done?

Both ozone problems, stratospheric depletion and tropospheric build-up, are created in large part by air pollution. The only practical approach to stopping the destruction of the ozone layer and to minimizing ozone pollution in our ambient air is reducing the human-generated pollutants that contribute to these problems. Ozone-depleting substances include classes of chemicals called chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) that are commonly used in refrigeration equipment, air conditioners, foam products, and fire suppression. Finding and using alternatives to ozone-depleting substances is an essential part of the solution. By 2020, the U.S. phased out the new production and import of most HCFCs and EPA's Significant New Alternatives Policy (SNAP) program has reviewed over 500 alternatives to ozone-depleting substances. As individuals, we can immediately repair any leaks in refrigerators, have our car and home air conditioners checked periodically, use alternatives to home air conditioning, and use alternatives to foam insulation and containers

Decreasing our use of vehicles burning fossil fuels and assuring our vehicle emission control systems are functioning properly is also critical to solving the problem of tropospheric ozone. We can use public transportation for long trips, walk or use bicycles for short trips, carpool to work, and combine several errands into one outing. Some areas have "ozone action days", which encourage citizens and industries to follow procedures to reduce their impact on the formation of harmful ozone. On these days, citizens are encouraged to postpone mowing their lawns and refilling their automobile's gas tanks until the evening hours, avoid using lighter fluid for charcoal, and carpool or use public transportation.

Adapted from the Air and Waste Management Association Environmental Resource Guide for Air Quality

EPA- 456/F 24 006