

COSMOS Cluster 3

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Smog in a Bottle

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References: *Atmospheric Chemistry and Physics*

J.H. Seinfeld and S.N. Pandis, 1997

Objectives:

1. To describe the role of ozone in forming smog particles from vapors emitted from an orange peel, and to form clouds in root beer using different particles
2. To characterize the effect of particles on light scattering in order to illustrate why smog looks "cloudy."

Introduction:

The atmosphere (and consequently the surface of the Earth where we live) is warmed or cooled depending on how much exiting heat is trapped or conversely by how much entering heat is reflected by the atmosphere. These two effects are controlled by the composition of vapors and particles in the atmosphere.

The first effect is frequently called "global warming" and refers to the efficiency with which the so-called "greenhouse gases" trap heat in the atmosphere. These gases (which include CO₂, H₂O, CFCs, etc.) act much like greenhouse walls in retaining heat energy in the atmosphere and preventing (temporarily) its release into space. These gases permit most of the sun's energy to pass through to the Earth's surface, but they trap the heat energy and keep it from radiating out from the upper atmosphere. In other words, the gases are transparent to the entering light waves but are not transparent to the escaping heat waves. This greenhouse effect is a natural process that keeps the Earth from being a frozen wasteland, but observational data show that there has been a measurable increase in the amount of some greenhouse gases (including CO₂) in our atmosphere coinciding with the advent of the Industrial Revolution. There is significant concern that the increased levels of greenhouse gases will lead to temperature changes that may have significant consequences for the Earth's climate (such as the melting of polar ice caps and the flooding of coastal regions). In the first part of this lab period, we will examine this effect by comparing the cooling rates of air in a flask with and without the pollution provided by CO₂ from a candle burning.

The second effect is associated with the fact that by scattering the incoming solar radiation, aerosol particles in the atmosphere can decrease the amount of energy that enters the atmosphere to start with, hence providing a cooling effect. Unlike the greenhouse gases, aerosol particles are

not transparent to incoming rays of sunlight and bounce some of the sun's energy back into space. In the second part of this lab period, we will show how ozone can help to form more "smog" particles and to grow existing particles bigger. Those particles can scatter light very efficiently, so that the beam of a laser pointer will be visible, whereas in the absence of particles, the beam is not visible as it travels through air.



"Gentlemen, it's time we gave some serious thought to the effects of global warming."

While the aerosol effect may be just as important as greenhouse gases in a small area, it is not globally distributed since particles tend to have a much shorter lifetime than gases (i.e. they tend to fall out of the air in a few days rather than the 40 years that many greenhouse gases last). For this reason it is important to characterize the particles in different regions of the Earth. In the next three lab periods, we will collect and study the local aerosol particles.

Equipment for each Group:

- 1 1-liter Erlenmeyer flask
- 1 stopper for flask with hole
- 1 stopper for flask with no holes
- 1 heat lamp
- 1 254-nm UVP pen lamp (not eye safe!)
- 1 orange
- 1 laser pointer

Procedure:

Part A:

A glass flask is used to simulate the Earth's atmosphere. A thermometer, which is placed inside the flask, is used to measure the change in air temperature. Using a heat lamp as a "sun," we will heat up the air in the flask. First, we will heat the flask by putting the stopper in and surrounding the side of the flask away from the heat lamp with tin foil (to speed the heating process). Point

the lamp at the flask, and turn it on for 10 min or until the thermometer reads about 40 °C. Then we will turn the lamp off and use a stopwatch to measure the decrease in temperature as a function of time. Use the table below to record your data, and then plot it on the chart provided below. The flask with air simulates the unpolluted atmosphere and this will serve as the "control" in your experiment.

1. Turn on your heat lamp to let it warm up.
2. Wrap the piece of tin foil completely around one side of the flask.
3. Take the stopper off the flask and carefully push the thermometer through the hole in the rubber stopper.
4. Place the flask 6" in front of the heat lamp.
5. When the thermometer reaches 40 °C, turn your lamp off. Move your flask away from the lamp, and immediately record the temperature on the first line of the table (this is Time 0).
6. At one-minute intervals, record the temperature in the table below.
7. After 15 min, remove the stopper and let the flask cool for 5 min.

Part B:

In this part of the lab you will test three sets of conditions to investigate how smog forms and how the particles in smog scatter light. You will investigate the scattering by shining a laser pointer through the flask. If there is not much scattering, you will not be able to see the laser beam. When the scattering is increased by the presence of particles you will see the path of the beam from where it enters to where it exits the flask.

The conditions necessary to prepare each flask are summarized in the table below. Tests B and C require making ozone in the flask. In order to do this, follow the steps below:

- 1) The ultraviolet pen lamp is assembled by connecting the cord and plugging it into a 110 VAC outlet. Since ultraviolet rays are harmful to the eye, it should only be operated (i.e. turned on) when it is in an enclosed (and shielded) space. **You must wear your UV-safe safety glasses during this entire lab**, as other students may be using the lamps during the lab period.
- 2) Carefully assemble the UVP Pen lamp. Turn off, then plug in.
- 3) Insert bulb into covered flask. Loosely place stopper on top.
- 4) Turn UVP lamp on.
- 5) Leave on for 5 min.
- 6) Turn UVP lamp off.
- 7) Quickly remove lamp from flask, then replace stopper. Your flask now will contain ozone.

In the table below describe the procedure you use in each of your tests and the results for each. Be sure to clean out the flask by rinsing with water between tests.

TEST	STEP BY STEP PROCEDURE	COMPONENTS	OBSERVATIONS
A	1. ADD ORANGE PEEL. 2. SHINE LASER THROUGH FLASK	1. AIR 2. ORANGE PEEL	LASER VISIBLE? NOTES:
B	1. MAKE OZONE IN FLASK. 2. SHINE LASER THROUGH FLASK.	1. AIR 2. OZONE	LASER VISIBLE? NOTES:

C	1. MAKE OZONE IN FLASK. 2. ADD ORANGE PEEL TO FLASK. 3. SHINE LASER THROUGH FLASK.	1. AIR 2. OZONE 3. ORANGE PEEL	LASER VISIBLE? NOTES:

Questions:

1. What difference do you observe when the orange peel is added to the flask with and without ozone?
2. What do the results from this experiment suggest about the size of particles that are present in the flasks in tests A and C? *Hint: Light scatters more efficiently when the particle size is similar to the wavelength of light passing through it. Visible light typically has wavelengths of about 1 μm .*
3. Which type of particle source is the orange? *Hint: Primary particle sources are those that emit particles directly, and secondary particle sources are those that emit vapors that result in particle growth after reaction in the atmosphere. (Additional hint: An orange smells when you remove the peel.)*
4. What is a possible difference between the tests A and C that would explain your results? *Hint: Commonly, atmospheric oxidation by ozone will form products with lower vapor pressures than the reactants. Those products will then tend to condense onto preexisting particles growing them to larger sizes.*
5. The mechanism by which ozone forms in this experiment (as well as in the polluted atmosphere) is photolysis of O_2 molecules. This means that incident rays of ultraviolet (ca. 254 nm wavelength) light split the O_2 molecule releasing two O radicals, each of which then joins with another O_2 molecule to form two O_3 molecules. Write the equation for this reaction.
6. Some components that exist in room air can also react to form condensable products (i.e. do you really need the orange?). How does your series of tests eliminate that possible explanation? *Hint: Remember test B.*