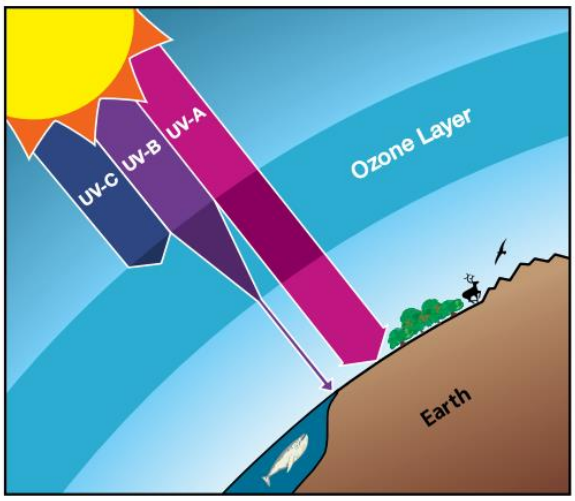
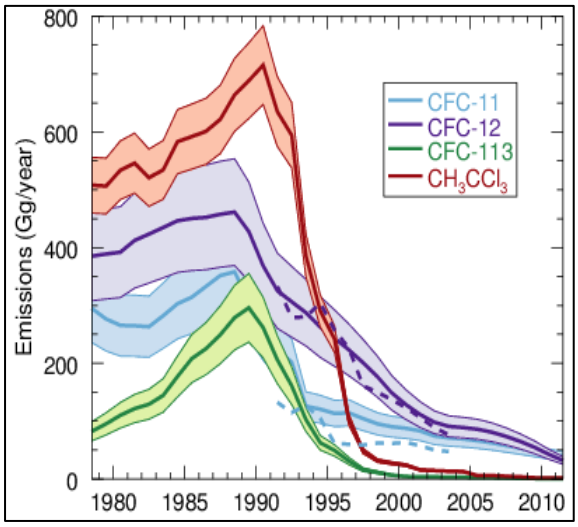
# Lab: Stratospheric Ozone

(modified from Teach Engineering & Center for Science Education)

**Background:** Ozone is made up of three oxygen molecules and occurs naturally in the stratosphere. That ozone is an important protective shield for life on Earth, filtering out more than 99% of ultraviolet rays from the sun before they reach us. Ultraviolet rays can cause sunburns, skin cancer, immune deficiencies and cataracts. Ozone in the stratosphere forms when oxygen molecules interact with ultraviolet rays from the sun. Under normal circumstances, ozone is continuously being destroyed and regenerated by the sun's ultraviolet rays. Beginning in the 1980's, scientists discovered "holes" in the ozone layer. These "holes" are not completely empty of ozone, but areas where the ozone concentrations are lower than under normal conditions, allowing more ultraviolet radiation to reach the Earth's surface. The only practical approach to stopping the destruction of the ozone layer was to reduce the amount of human-created pollutants that contribute to its depletion. The most common ozone-destroying pollutants are in a class of chemical compounds called chlorofluorocarbons (CFCs), which were once used in air conditioner refrigerator coolants, cleaning solvents, plastic foam manufacturing and aerosol spray propellants. In 1987, CFCs were banned internationally with the Montreal Protocol.

When an ozone molecule absorbs UV light from the sun, it breaks down into an oxygen (O2) molecule and an oxygen atom (O). Sometimes the oxygen molecule breaks into two oxygen atoms as well. Normally, the free oxygen atom combines with other oxygen atoms or molecules to produce ozone again. When there are no outside disturbances, this process of breaking down ozone and building it back up occurs at a constant rate that keeps us protected from a lot the sun's harmful UV rays. However, harmful pollutants (such as CFCs) can also break down ozone by converting it into oxygen molecules and atoms. When this happens, ozone breaks down much faster than it can build up and "holes" appear in the ozone layer. In today's activity, you will model how pollutants destroy ozone.




**Prelab Questions:**

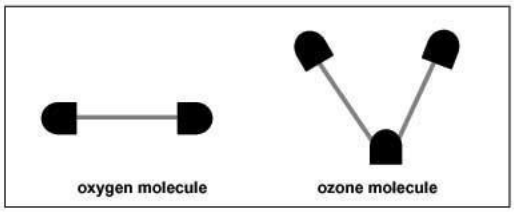
1. What is ozone and where is the ozone layer found?

2. Why is the ozone layer important to life on Earth?

3. Describe natural and anthropogenic methods of ozone destruction.

**Procedure:**

1. You will be using mini marshmallows and toothpicks to make oxygen molecules (two mini marshmallows connected by a toothpick), ozone molecules (three mini marshmallows connected by two toothpicks) and free oxygen (single mini marshmallows). The toothpicks represent the chemical bonds and hold the molecules together. Set up the simulation by making 25 ozone molecules and 25 oxygen molecules on your table, then add 50 individual free oxygens to the mixture.



2. NATURAL CYCLING: Choose an even number of students to be "Ozone Makers" and "UV Destroyers". (If there are four people at your table, go with two of each – If there are three people at your table, go with one of each with the third person being a timer)
    a. Ozone Makers create as many ozone molecules as possible by connecting oxygen molecules with free oxygen using the toothpicks.
    b. UV Destroyers destroy as many ozone molecules as possible by breaking the chemical bonds (ripping marshmallows off) and leaving oxygen molecules, free oxygen and toothpicks behind.
3. You will have 60 seconds to create/destroy as much oxygen and ozone as possible.
4. After 60 seconds, count and record the amount of each molecule remaining and record the data in Table 1.
5. Reset the table with 25 ozone molecules, 25 oxygen molecules and 50 individual free oxygen.
6. HUMAN IMPACT: Choose one student to be an "Ozone Maker" and two to be "UV Destroyers". (If there are four people at your table, the fourth will be a timer)
    a. The Ozone Maker creates as many ozone molecules as possible by connecting oxygen molecules with free oxygen using the toothpicks.
    b. UV Destroyers and the CFC Destroyer destroy as many ozone molecules as possible by breaking the chemical bonds (ripping marshmallows off) and leaving oxygen molecules, free oxygen and toothpicks behind.
7. You will have 60 seconds to create/destroy as much oxygen and ozone as possible.
8. After 60 seconds, count and record the amount of each molecule remaining and record the data in Table 2.
9. Share data with other groups to calculate the average percent change in ozone for Natural Cycling and Human Impact.

**Data: Table 1. Natural Cycling vs Human Impact**

| | Final # of Free Oxygen | Final # of Oxygen ($O_2$) | Final # of Ozone ($O_3$) | % Change in Ozone Abundance |
|---|---|---|---|---|
| **Natural Cycling** | | | | |
| **Human Impact** | | | | |

**Table 2: Class Data of Percent Change in Ozone Abundance**

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | CLASS AVG |
|---|---|---|---|---|---|---|---|---|---|---|
| % Change Natural | | | | | | | | | | |
| % Change Human Impact | | | | | | | | | | |

**Analysis Questions:**

4. Identify the independent variable and dependent variable in the experiment above.

5. Analyze the ratio of ozone molecules and oxygen molecules under natural cycling conditions.

6. How does the amount of free oxygen atoms affect rates of natural cycling?

7. Analyze the ratio of ozone molecules and oxygen molecules under conditions of human impact.

8. How do humans impact stratospheric ozone levels?

9. How does stratospheric ozone differ from tropospheric ozone? (not given in lab)

10. The Montreal Protocol, resulting in the banning of CFCs, is often considered one of the biggest environmental success stories of all time. Why do you think this is so?