A SPIN ON OZONE
(Thanks to Tamsin Gray, British Antarctic Survey, United Kingdom)

Lesson at a glance

Students act out the formation of the polar vortex
and the destruction of the ozone layer above Antarctica.

Background

The ozone layer is located around 20 kilometres above us in a layer of the atmosphere called the stratosphere. Each year above Antarctica, a dramatic destruction of ozone takes place resulting in levels of ozone in the atmosphere dropping to around one-third of their usual value.

Chlorofluorocarbons (CFCs) are a family of chemical compounds that were developed in the 1930s as safe alternatives for refrigeration and spray can propellants. CFCs are highly stable. They accumulate in the stratosphere where they can last for up to 100 years. During that time, they can do a lot of damage to the ozone layer. In the presence of ultraviolet radiation from the Sun, CFCs break up and release their chlorine atoms. The chlorine then reacts with ozone (O<sub>3</sub>), removing one oxygen atom to form chlorine monoxide (ClO) and leaving an oxygen molecule (O<sub>2</sub>).

During the Southern Hemisphere winter, a vortex forms in the Antarctic stratosphere, preventing warmer air from lower latitudes from reaching the centre of the vortex. Inside the polar vortex, the air is extremely cold and polar stratospheric clouds (PSCs) made of ice crystals often form when temperatures drop below −75°C.

These ice clouds provide a surface where the chemical reaction that destroys ozone can take place. Since sunlight is needed for this reaction, the ozone hole does not start to form until light returns at the end of the long dark Antarctic winter. The combination of extremely cold temperatures (which allow PSCs to form), sunlight, and the presence of CFCs results in the formation of an ozone hole over Antarctica in the austral spring time. The vortex breaks down at the end of spring and ozone-rich air from outside moves in to refill the hole.

Time

Preparation: 5–10 minutes
Class time: 15–20 minutes

Materials
(per class)

- 10 inflated balloons
- bowl or plate (plastic or metal recommended)
- 1 straightened paperclip or toothpick
- several willing volunteers

![Figure 1.10 The maximum extent of the ozone hole above Antarctica over the past 40 years. Violet shows the area of lowest ozone concentrations, with red indicating the highest.](image)

![Figure 1.11 Polar stratospheric clouds are ice clouds formed high up in the atmosphere (around 20 km) when the temperature drops below −75°C. Chemical reactions that destroy ozone gas take place on the surfaces of these beautiful and unusual looking clouds.](image)
Activity Directions
1. Pick four or five volunteers to hold hands in a circle and walk around in one direction—they are the polar vortex.
2. Choose one volunteer to be the Sun. The Sun begins the activity crouched in the middle of the polar vortex, holding a paperclip or toothpick to represent the CFCs.
3. Place a bowl or plate of inflated balloons inside the polar vortex—the balloons are molecules of ozone, and the bowl or plate is a polar stratospheric cloud.
4. The Sun rises and begins to destroy the ozone using the CFCs (i.e., breaks the balloons).
5. Other volunteers try to bring more balloons in from outside but cannot due to the barrier of the polar vortex.
6. The polar vortex breaks up (it is now Antarctic summer) and outside volunteers succeed in bringing in new ozone to replace that which was destroyed.

Note: Do not let the polar vortex continue to spin for too long or the volunteers may suffer!

Discussion
1. Does an ozone hole form over the Arctic? (Small holes can form over the Arctic but it is not usually cold enough there to form the ice clouds on which reactions take place. There is no polar vortex isolating the Arctic stratosphere, so warmer air from lower latitudes can flow in.)
2. Why is the ozone hole a problem for us? (Ozone is currently being destroyed faster than new ozone is being made. This not only raises the risk of skin cancer in humans; it can also have a negative effect on other animals and plants. The ozone layer also plays an important role in global climate and is now thought to be largely responsible for the rapid warming of the Antarctic Peninsula region over the past few decades. This warming has caused floating ice shelves to disintegrate, allowing glaciers to flow faster into the sea and contributing to global sea level rise.)
3. What will happen to the ozone hole in the future? (Although the use of CFCs has slowed down dramatically since the Montreal Protocol came into force, they remain in the atmosphere for a long time. The ozone layer is recovering slowly but it probably will not have fully recovered until at least 2070.)
4. What is the difference between the ozone in the stratosphere and ground level, or tropospheric, ozone? (Chemically, there is no difference—it is just where it is located. Ozone in the stratosphere helps protect us from dangerous levels of ultraviolet radiation. Ozone in the air we breathe is a pollutant that results from human activities such as industrial emissions and automobile exhaust, especially during hot weather. It is corrosive and can damage people's lungs, as well as harming other animals and plants.)

Extensions/Adaptations
1. Instead of balloons, use two different colour building blocks that snap together (e.g., green to represent chlorine from the CFCs and yellow for oxygen). The Sun would then start with a number of 'ozone' molecules (3 yellow blocks snapped together). When the reaction begins, the Sun would break apart the ozone molecules, then attach one of the oxygen atoms to the chlorine atom (to form ClO) and rejoin the two other oxygen atoms (to form O₂).
2. For high school chemistry students, make the chemical reactions more accurate and complicated. Have the students research the process (see web links to this activity on the CD-ROM for more information) and challenge them to create more accurate models using materials such as building blocks, or through an interactive medium such as drama or interpretive dance.