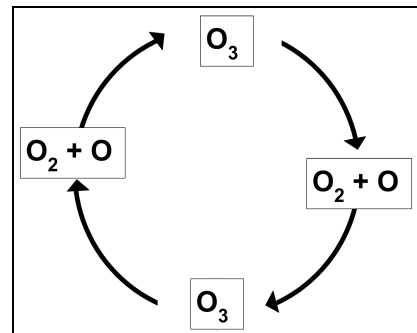


Ozone Layer Depletion

Name: _____

Date: _____ Per: _____

The ozone layer is a part of the stratosphere that has a high concentration of ozone molecules. Ozone forms when the energy in UV radiation causes oxygen atoms to bond with oxygen molecules and form ozone (O_3). At the same time, the energy in the UV radiation can break other ozone molecules back down into oxygen atoms and oxygen molecules. Thus, formation of ozone in the presence of sunlight and its subsequent breakdown is a cycle that can occur indefinitely as long as there is UV energy entering the atmosphere. Under normal conditions, the amount of ozone in the stratosphere remains at a steady state.

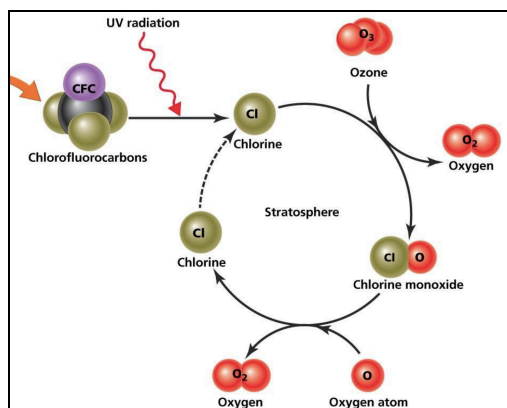


1. In the diagram above, why does the level of ozone in the atmosphere remain **constant**?

The ozone layer is important to life on earth because it absorbs most of the UVB solar radiation that enters the earth's atmosphere. For plants, increased exposure to UVB radiation can be harmful to plant cells and reduce rates of photosynthesis. In humans, increased exposure to UVB radiation can cause skin cancer and eye problems like cataracts. Increases in skin cancers have already been recorded, especially in countries near the Antarctic ozone hole such as Chile and Australia.

2. What are the impacts of UVB radiation on plants and humans?

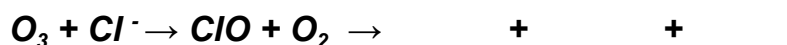
The "holes" in the ozone layer are not completely empty of ozone, but they contain less-than-normal ozone levels and allow more UVB radiation to reach the Earth. Ozone "holes" currently exist over Antarctica, the northern half of the U.S. into Canada, and northern Europe and Tibet.



The cause of the "holes" in the ozone layer is from a specific type of pollutant known as chlorofluorocarbons, or **CFCs**. CFCs are a chemical that was once commonly used in refrigerants, coolants, aerosol spray cans, cleaning solvents, and styrofoam. When CFCs are released in the troposphere, some of them can make their way into the stratosphere.

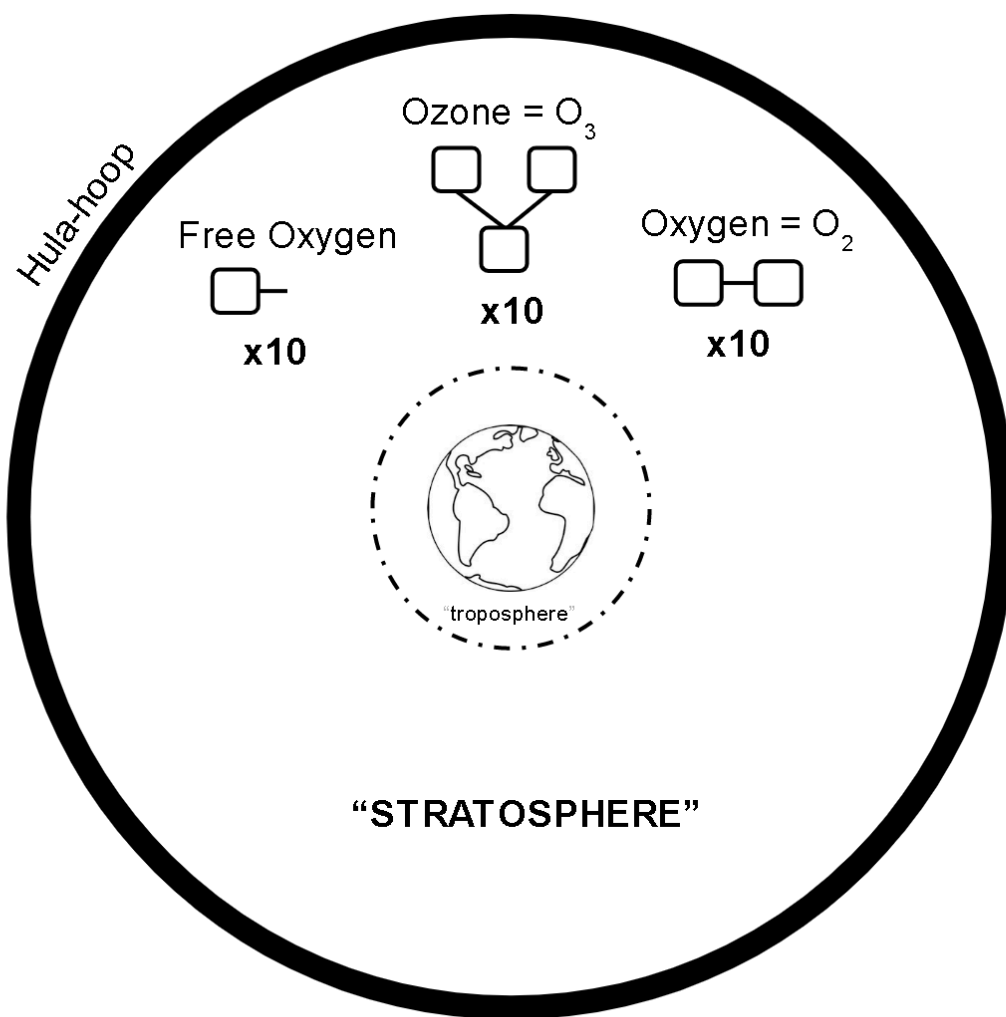
UV light can free a **chlorine (Cl)** ion from the CFC, which then breaks apart an ozone molecule from $O_3 \rightarrow O_2 + O$. One chlorine atom can break apart thousands of ozone molecules, resulting in a net loss of ozone molecules in the stratosphere

3. Use the information above to complete the equation for ozone depletion:



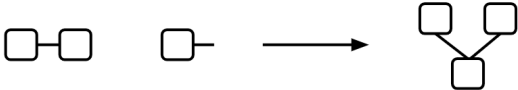
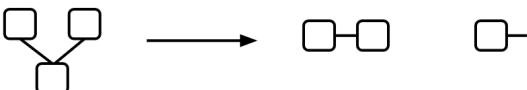
SET-UP INSTRUCTIONS:

1. Place hula-hoop on the table to represent the stratosphere. Use chalk to draw a small earth and a dotted line around the earth to represent the troposphere.
2. Label the area between the hula-hoop and the troposphere "stratosphere."
3. Use marshmallows and toothpicks to create the molecules below and distribute them evenly in the stratosphere.
 - 10 Oxygen atoms = O
 - 10 Ozone molecules = O₃
 - 10 Oxygen molecules = O₂



SCENARIO 1

4. **Assign one person** in your group to be the “ozone maker” and **a different person** to be the “ozone breaker.” Both of these students should **write “UVB”** on the top of both of their hands.
5. Set a timer for two minutes, and allow the “ozone maker” to use the free materials in the stratosphere to make ozone molecules while at the same time “ozone breaker” breaks apart ozone molecules into O_2 and O . **DO NOT RACE**, just go at a similar steady pace.

Ozone Maker	Ozone Breaker
	
$O_2 + O \rightarrow O_3$	$O_3 \rightarrow O_2 + O$

6. Count the number of molecules in the stratosphere after 2 minutes

O_3 : _____ O_2 : _____ O : _____

7. *Why didn't you run out of ozone molecules at the end of two minutes ?*

8. *Where does the energy come from to make and break-down ozone molecules?*

9. *What did you model in this scenario?*

- The role of CFCs in the breakdown of the ozone layer.*
- The natural formation/breakdown of ozone in the stratosphere*
- The hole in the ozone layer*

SCENARIO 2

10. The UV “ozone maker” and the UV “ozone breaker” should keep their roles. In addition, **choose two new people to be “CFCs.”** These two new people should **write “CFC”** on both of their hands.

11. Return to the original number of molecules:

- 10 Oxygen atoms = O
- 10 Ozone molecules = O₃
- 10 Oxygen molecules = O₂

12. Set a timer for two minutes, and allow the UV “ozone maker” to use the free materials in the stratosphere to make ozone molecules again while at the same time the UV “ozone breaker” **AND** the “CFCs” break apart ozone molecules.

13. Count the number of molecules in the stratosphere after 2 minutes

O₃: _____ O₂: _____ O: _____

14. *Did you end up running out of ozone molecules? Why?*

MONTREAL PROTOCOL

The Montreal Protocol of 1987 is an international treaty that was signed by over 180 nations that agreed to **stop the use of CFCs in industry**. Since then, the levels of ozone in the atmosphere have started to increase and repair the “hole.” The repair is happening slowly since it takes a long time for existing CFCs to work their way out of the stratosphere, but we are likely to see a complete recovery of the ozone layer within our lifetime.

14. In the box above, copy the term “MONTREAL PROTOCOL” in **large letters**. Then, add the **subscript number “3”** to every letter “O” in the term to help you remember that the Montreal Protocol protects the ozone layer (O₃).

AP OZONE DEPLETION PRACTICE QUESTIONS

1. Addressed the issue of stratospheric ozone depletion
 - a. Endangered Species Act
 - b. Kyoto Protocol
 - c. Montreal Protocol
 - d. National Environmental Policy Act
 - e. Wilderness Act
2. Which of the following best describes the advantage of using hydrofluorocarbons (HFCs) or hydrochlorofluorocarbons (HCFCs) to replace chlorofluorocarbons (CFCs) in industrial processes?
 - a. HFCs and HCFCs have lower ozone-depleting potentials than CFCs do.
 - b. HFCs and HCFCs are more stable than CFCs are in the atmosphere.
 - c. HFCs and HCFCs are not classified as greenhouse gasses but CFCs are.
 - d. HFCs and HCFCs are less expensive to produce than CFCs are.
3. Considered harmful in the troposphere but beneficial in the stratosphere:
 - a. Sulfur dioxide
 - b. Lead
 - c. Ozone
 - d. Lead
4. Which of the following best describes the importance of ozone in the stratosphere to life on Earth?
 - a. Ozone reflects X-rays from the Sun back into space.
 - b. Ozone absorbs most of the ultraviolet radiation from the Sun.
 - c. Ozone helps to moderate surface temperature by absorbing CO₂ and CH₄.
 - d. Ozone increases mutation rates and accelerates evolution in a variety of species.
5. Which of the following describes a negative effect of substituting hydrofluorocarbons (HFCs) for chlorofluorocarbons (CFCs) in an effort to reduce ozone depletion?
 - a. Hydrofluorocarbons are expensive to produce and are not widely used in industry.
 - b. Some type of hydrofluorocarbons are greenhouse gasses that contribute to global climate change.
 - c. Hydrofluorocarbons can interact with NO_x and VOCs in the troposphere to produce photochemical smog.
 - d. High levels of hydrofluorocarbons in the stratosphere can lead to physiological stress and decreased growth in plants.
6. Stratospheric ozone depletion is most likely to result in which of the following?
 - a. Increased growth of food crops due to increasing amounts of ultraviolet radiation
 - b. Extended grazing season for cattle
 - c. Disruption of photosynthesis in plants
 - d. Increased movement of the human population toward equatorial regions

FRQ Practice

Ozone (O_3) is an atmospheric trace gas that occurs naturally in the stratosphere. It is also formed as a consequence of human activity in the troposphere, immediately above Earth's surface. The location of ozone in the atmosphere determines whether the gas protects or damages the environment.

- a. **Identify** the type of solar radiation that is absorbed by stratospheric ozone, and **describe** one human health benefit that results from the absorption of this solar energy.

- b. The absorption of solar energy by stratospheric O_3 causes ozone molecules to undergo chemical decomposition and formation. **Describe** the chemical processes that lead to this natural balance between decomposition and formation of stratospheric O_3 (you may use chemical equations).

- c. The Montreal Protocol of 1987 provided a global framework to phase out chlorofluorocarbon (CFC) production and use. Although the Montreal Protocol has led to a dramatic decrease in CFCs released into the atmosphere, stratospheric ozone destruction has decreased only slightly.

- i. **Explain** the process by which CFCs lead to the destruction of stratospheric ozone. (You may use chemical equations in your answer.)

- ii. **Explain** why the rapid decrease in CFC emissions has not led to a similarly rapid decrease in the destruction of stratospheric ozone.

- d. **Identify** a human activity that leads to the formation of tropospheric ozone as a secondary pollutant and explain why tropospheric ozone levels peak in the daytime.

- e. **Identify** one negative ecological impact and one negative human health impact that result from the formation of tropospheric ozone.