Topic 9.1

Stratospheric Ozone Depletion

You Will Learn to:

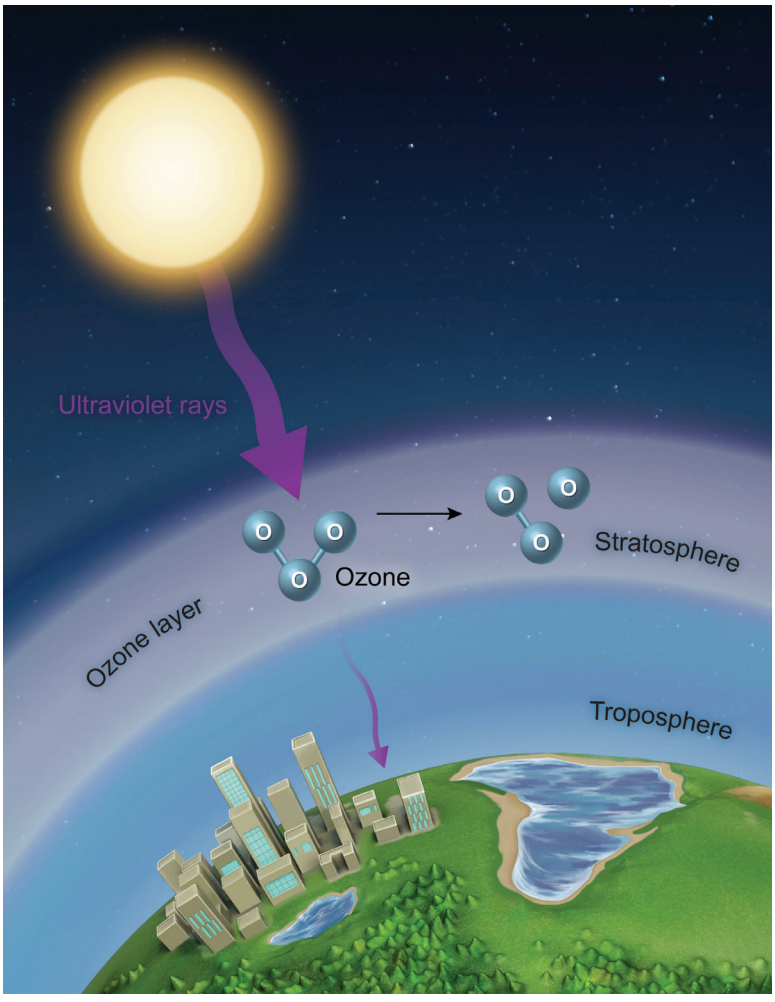
- Describe the role of stratospheric ozone and how it impacts life on Earth.

By the End of the Topic, You Should Be Able to Answer:

- What is the role of the stratospheric ozone layer?
- What causes the depletion of stratospheric ozone?
- What are the effects of depleted stratospheric ozone?

Stratospheric Ozone Layer

Ozone (O_3) is an atmospheric gas that accumulates in both the troposphere and the lower stratosphere. In the troposphere, O_3 is a harmful pollutant that contributes to photochemical smog. However, in the stratosphere, O_3 is a vital gas that ensures the health and survival of life on Earth.



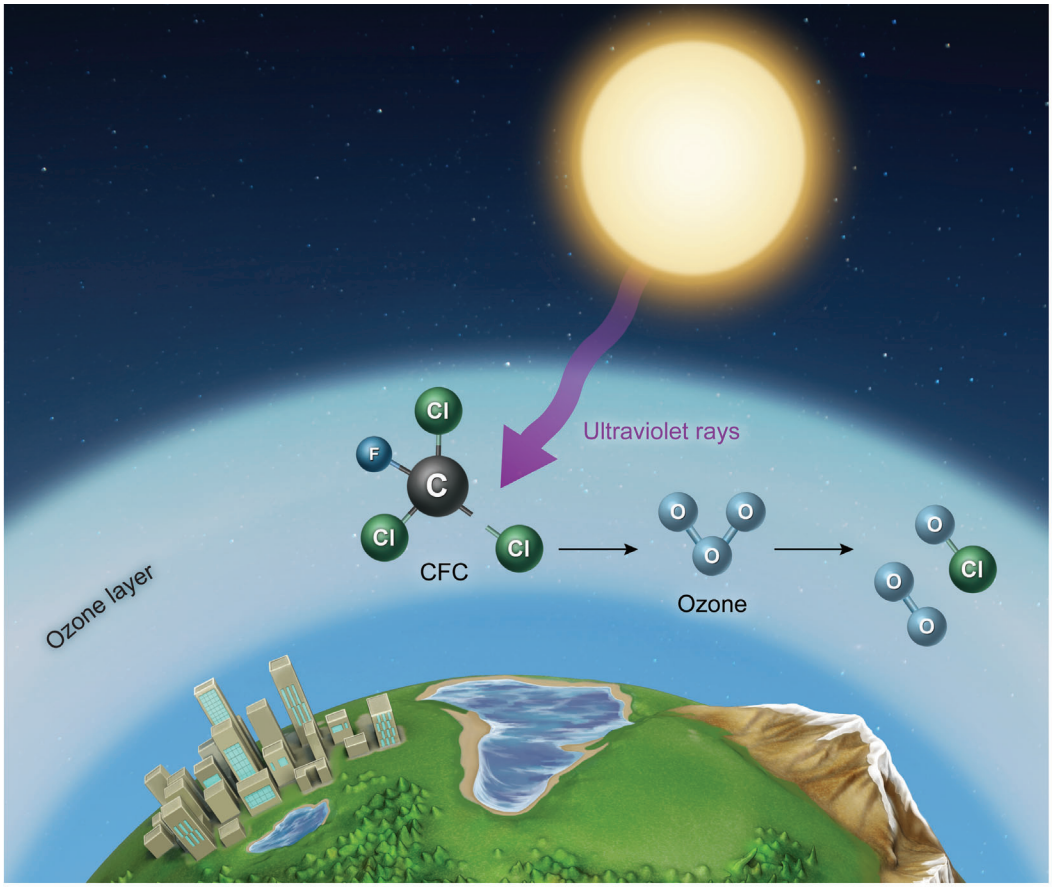
O_3 forms a layer in the stratosphere, known as the **O_3 layer**, where it absorbs harmful ultraviolet (UV) rays from the Sun. As O_3 absorbs UV rays in the stratosphere, it breaks down into an oxygen molecule and oxygen atom:

$$O_3 + UV \rightarrow O_2 + O$$

UV rays are harmful to living organisms because they can damage DNA and lead to skin cancer as well as cataracts in both animals and humans. The absorption of these rays by the O_3 layer allows organisms to remain healthier for longer, increasing their ability to survive and reproduce, which is important for evolution.

Stratospheric Ozone Depletion

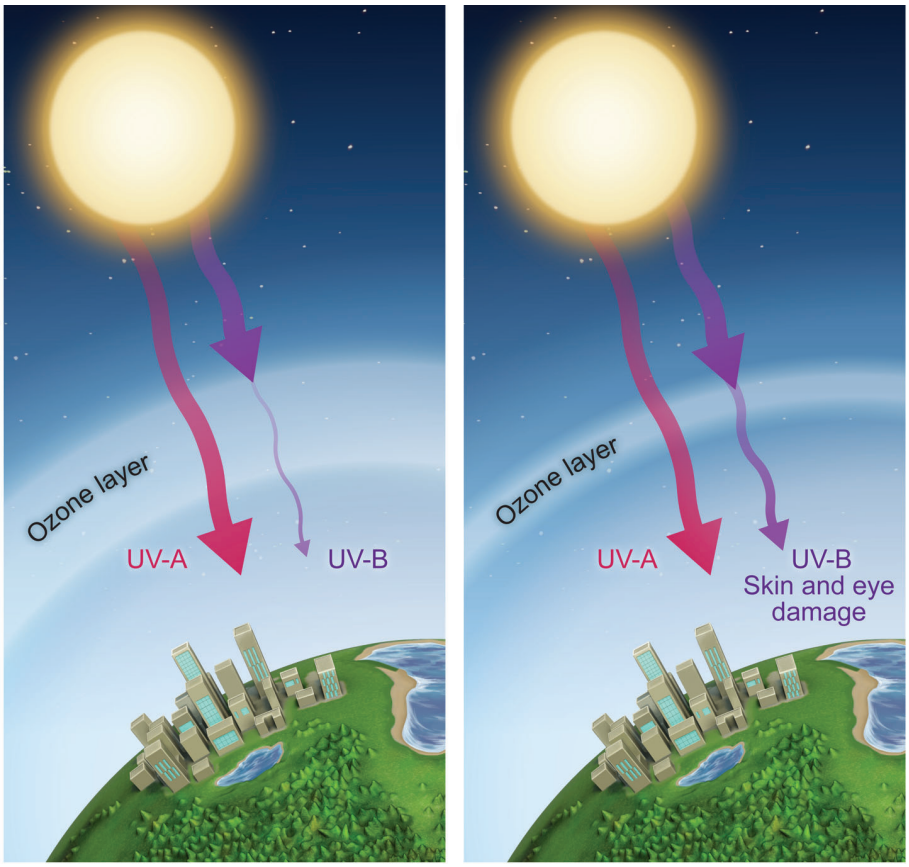
Although UV can naturally break down O_3, the depletion of the O_3 layer is triggered by the release of O_3-depleting chemicals, such as **chlorofluorocarbons (CFCs)**. CFCs were synthesized in the early 20th century as an inexpensive and effective group of gases that could be used in aerosol sprays and cooling systems.



When CFCs are released and reach the stratosphere, UV light begins to break these chemicals down, releasing chlorine atoms. At the poles, this breakdown is enhanced by ice crystals that provide a surface for the reaction. As the ice crystals melt in the spring, the chlorine atoms catalyze the destruction of O_3, leading to a hole in the O_3 layer.

$$Cl + O_3 \rightarrow ClO + O_2$$

The combination of these natural factors and human activities has contributed to the depletion of the layer over time. Each year, seasonal depletion creates a hole in the O_3 layer over both the North and South poles, with the largest depletion occurring over Antarctica from August through October.



Normal ozone layer **Depleted ozone layer**

Because the O_3 layer primarily absorbs the more harmful UV rays, such as UV-B, while minimally absorbing less harmful UV rays, such as UV-A, the depletion of the O_3 layer will result in an increase in harmful rays that reach Earth's surface.

This increase can negatively impact human health and the environment in many ways, such as decreasing productivity. To prevent these negative impacts caused by O_3 depletion, mitigation strategies have been implemented (see Topic 9.2).

Things to Remember

- Stratospheric ozone (O_3) is important for the health and evolution of life on Earth because it absorbs many of the ultraviolet (UV) rays that can be harmful to animals and humans.
- Anthropogenic causes of stratospheric O_3 depletion include the emission of chlorofluorocarbons, a group of gases used extensively in the early 20th century.
- Stratospheric O_3 depletion can lead to skin cancers and cataracts in humans due to increased UV rays that reach the Earth's surface.

9.1 Vocabulary

Chlorofluorocarbons (CFCs)	A group of ozone-depleting gases that were previously used in aerosol sprays and cooling systems.
Ozone layer	Accumulation of ozone gas in the stratosphere that blocks harmful ultraviolet rays from reaching Earth’s surface.

9.1 Check for Understanding

1. **Which of the following best describes the stratospheric ozone layer?**

   A. An atmospheric layer that functions as the buffer between the troposphere and stratosphere

   B. A large concentration of ozone gas that contributes to photochemical smog

   C. An accumulation of ozone gas that protects Earth's surface from harmful UV rays

   D. A formation of secondary pollutants that cause skin cancer and cataracts in humans

2. **How do UV rays impact life on Earth?**

   A. UV rays can lead to skin cancer and cataracts.

   B. UV rays can lead to increased evolutionary rates.

   C. UV rays can lead to increased biodiversity.

   D. UV rays can lead to decreased global temperatures.

3. **Which gases released by human activities contribute to depleted ozone?**

   A. Carbon dioxide

   B. Oxygen

   C. CFCs

   D. Water

Topic 9.2

Reducing Ozone Depletion

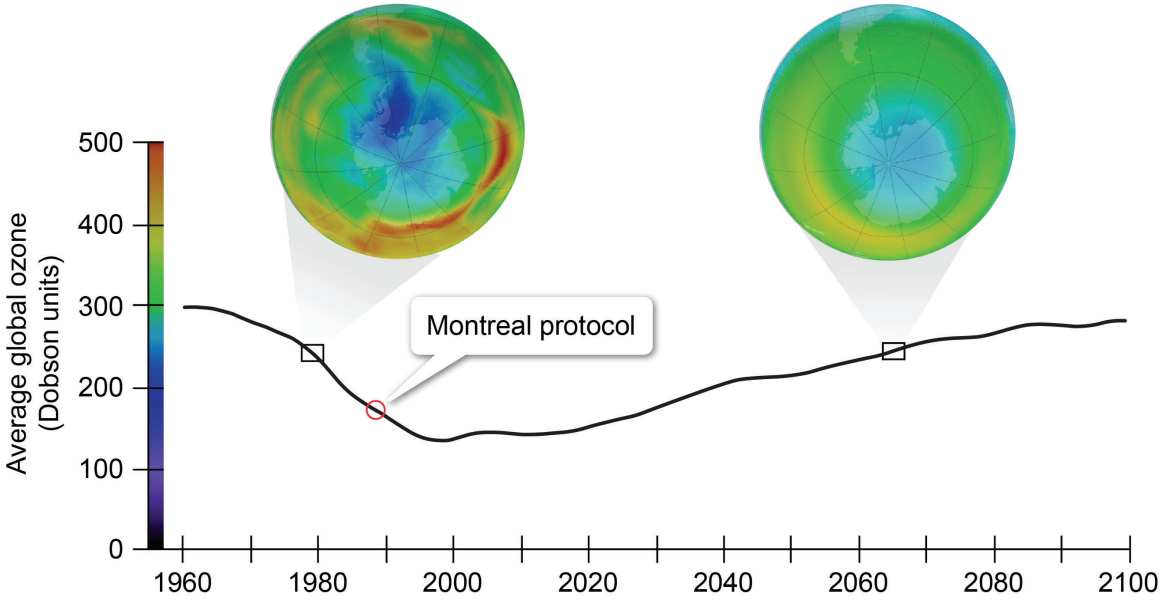
You Will Learn to:

- Identify alternatives for chlorofluorocarbons (CFCs) that can be used to reduce ozone depletion.

By the End of the Topic, You Should Be Able to Answer:

- What was the Montreal Protocol?
- What chemicals can replace CFCs?
- What is a drawback to using CFC replacements?

Montreal Protocol



The discovery that chlorofluorocarbons (CFCs) were contributing to the increased depletion of the stratospheric ozone (O_3) layer (see Topic 9.1) resulted in efforts to reduce the global use of these harmful chemicals. In 1987, scientists and politicians drafted the **Montreal Protocol**, which is a global environmental treaty that contains provisions to reduce the production and use of ozone-depleting chemicals.

After the protocol was created, manufacturers began implementing strategies to replace CFCs with chemical substitutes, such as hydrocarbons and **hydrofluorocarbons (HFCs)**, that do not deplete the O_3 layer. Since the implementation of the protocol, noticeable improvements have been detected in the O_3 layer in recent years. However, some of these substitutes, especially HFCs, are strong greenhouse gases that can contribute to global climate change (see Topic 9.5).

Things to Remember

- Mitigation efforts to reduce ozone (O3) depletion include replacing ozone-depleting chemicals, like chlorofluorocarbons (CFCs), with substitutes that do not deplete the O3 layer, such as hydrofluorocarbons (HFCs).

9.2 Vocabulary

Hydrofluorocarbons (HFCs)	A group of greenhouse gases that were created as a substitute for chlorofluorocarbons (CFCs).
Montreal Protocol	International treaty signed in 1987 that contains provisions to reduce the production and use of ozone-depleting chemicals.

9.2 Check for Understanding

1. **Which of the following inspired the reduction of CFC use?**

   A. A political campaign to reduce the use of greenhouse gases

   B. The scientific discovery that CFCs deplete the ozone layer

   C. A social movement to prevent synthesis of chlorine atoms

   D. Technological improvements that changed refrigeration methods

2. **Which of the following pieces of legislation focused on decreasing the use of CFCs?**

   A. RCRA

   B. CERCLA

   C. Montreal Protocol

   D. Kyoto Protocol

3. **Which of the following is a common replacement for CFCs?**

   A. HFCs

   B. Chlorine gas

   C. Methane

   D. UV