# A protective layer of gas

Ozone, $O_3$, has three oxygen atoms. Most atmospheric ozone is in the stratosphere, above the troposphere. This diffuse gas layer is not a solid shell.

## 1. LESS OZONE MEANS LESS UV PROTECTION

**OZONE LOSS**

Fewer ozone molecules in the stratosphere

→

**LESS ABSORPTION**

More UV-B passes through the atmosphere

→

**SURFACE EFFECT**

Greater UV-B exposure for living organisms

Ozone absorbs radiation rather than simply reflecting it away. Reduced UV exposure helped make life on land possible and continues to protect organisms. Some UV still reaches the surface even when the ozone layer is not depleted.

## 2. WHICH ULTRAVIOLET RADIATION?

The Sun emits UV-A, UV-B and UV-C. Ozone absorbs most UV-B; ozone and ordinary oxygen together absorb UV-C before it reaches the ground. UV-A is not significantly absorbed by ozone. Ozone depletion therefore particularly increases UV-B at the surface, rather than increasing every wavelength equally.

## 3. WHY LIVING THINGS ARE AFFECTED

UV-B can damage DNA. Greater exposure increases human risks of skin cancer and cataracts, which cloud the eye's lens. It can also impair plant processes and harm phytoplankton. Damage to primary producers can affect the organisms that depend on them, although effects vary among species and conditions.

Same molecule, different location: stratospheric ozone filters UV; high concentrations of tropospheric ozone harm lungs and plants. Ground-level ozone pollution cannot replace the protective layer above.

Ozone location and ground-level contrast: NASA Ozone Watch, What Is Ozone?
UV absorption and the protective layer: US EPA, Basic Ozone Layer Science.
DNA, eye and ecosystem effects: US EPA, Health and Environmental Effects.

Scope: College Board APES CED, Topic 9.1, STB-4.A.1-3, p. 182.

# How CFCs accelerate ozone loss

Chlorofluorocarbons (CFCs) contain carbon, chlorine and fluorine. Their former uses included refrigeration, aerosol propellants and foam manufacture.

## 1. FOLLOW THE CHEMICAL FROM RELEASE TO EFFECT

| | |
|---|---|
| **A. Release** | CFCs escape from products or equipment into the lower atmosphere. |
| **B. Transport** | Their stability lets them persist and eventually mix into the stratosphere. |
| **C. Breakdown** | High-energy UV breaks CFC molecules, releasing reactive chlorine. |
| **D. Ozone loss** | Chlorine participates in cycles that convert ozone to ordinary oxygen. |

## 2. SUPPORTING CHEMISTRY: A CATALYTIC CYCLE

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

$$ClO + O \rightarrow Cl + O_2$$

---

$$\text{Net: } O_3 + O \rightarrow 2\,O_2$$

Cl is regenerated, so one chlorine atom can destroy many ozone molecules. O denotes an oxygen atom; ClO is chlorine monoxide. The chlorine atom is reactive, not a chloride ion ($Cl^-$).

## 3. DEPLETION IS A CHANGE IN THE BALANCE

Ozone is naturally formed and broken down. Extra chlorine and bromine can increase destruction relative to formation. The cycle above illustrates catalysis and is important at low and middle latitudes; other chlorine and bromine cycles dominate rapid polar ozone loss.

CFC uses, persistence and UV breakdown: US EPA, Basic Ozone Layer Science.
Reaction equations and catalytic regeneration: NOAA, Twenty Questions (2018), Q8.
Natural formation and destruction: NASA Ozone Watch, What Is Ozone?

Scope: College Board APES CED, Topic 9.1, STB-4.A.1-3, p. 182.

# Why the Antarctic spring?

Human-produced ozone-depleting substances are widely distributed. Antarctic weather and seasonal sunlight create conditions that make ozone loss especially severe.

## 1. THE SEASONAL SEQUENCE

| | |
|---|---|
| **A. Cold winter** | An isolated polar vortex traps very cold stratospheric air. Polar stratospheric clouds form. |
| **B. Cloud chemistry** | Reactions on cloud-particle surfaces convert stored chlorine compounds into forms that sunlight can activate. |
| **C. Spring sunlight** | Returning sunlight releases reactive chlorine. Catalytic reactions rapidly destroy ozone. |
| **D. Later warming** | Clouds disappear and the vortex weakens. Mixing with ozone-rich air helps end the seasonal hole. |

Key interaction: ozone-depleting chemicals + cold cloud surfaces + returning sunlight. Melting ice alone does not explain the chemical destruction of ozone.

## 2. AN OZONE "HOLE" IS SEVERE THINNING

The term describes unusually low ozone over a large region, not a literal opening with no atmosphere. Ozone depletion also occurs outside Antarctica. The annual size and depth of the polar hole depend on chemical loading and weather; one unusual year does not establish the long-term trend.

## 3. KEEP DEPLETION AND WARMING DISTINCT

Ozone depletion reduces the atmospheric UV shield. The enhanced greenhouse effect concerns gases absorbing and emitting outgoing infrared radiation. They are different processes, although some gases such as CFCs contribute to both. An ozone hole is not the main cause of global warming.

Cold clouds, sunlight and vortex breakup: NASA Ozone Watch, Ozone Hole Facts.
Ozone holes, variability and climate distinction: NOAA, Twenty Questions (2022).

Scope: College Board APES CED, Topic 9.1, STB-4.A.1-3, p. 182.