Ozone

What is Ozone?
The term itself comes from the Greek word meaning "smell," a reference to ozone's distinctively pungent odor. This odor is noticeable directly after a close lightning strike or when an electric motor is turned on. Ozone ($O_3$) is a gas that forms in the atmosphere when 3 atoms of oxygen are combined. It is not emitted directly into the air. At ground level it is created by a chemical reaction between oxides of nitrogen (NO$_x$) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs high above the Earth or at ground level. Ozone is considered "good" or "bad" depending on its location in the atmosphere. Life as we know it is possible in part because of the protection afforded by the upper ozone layer. But over the past half-century, humans have placed this ozone layer in jeopardy. We have unwittingly polluted the air with chemicals that threaten to eat away the life-protecting shield surrounding our planet.

What is the ozone layer?
The ozone layer is actually a band of gas located in the stratosphere that has especially high concentrations of ozone molecules. This band is found between 10 and 30 miles above the Earth's surface. An ozone molecule consists of three oxygen atoms that are bound together and form a wide "V" shape. Its formula is $O_3$. These ozone molecules are continually being created in the stratosphere. This creation of ozone occurs when ultraviolet radiation in the range of 2400 angstroms (an angstrom is a measurable wavelength of energy) strikes a diatomic molecule of oxygen ($O_2$) breaking the oxygen into two single atoms of oxygen. These individual atoms of oxygen are very reactive so they readily combine with another diatomic $O_2$ molecule to form $O_3$ or ozone.

Just as $O_3$, is continually being created in the stratosphere, it is also continually being destroyed. When ozone is struck by ultraviolet radiation, it breaks into a molecule of diatomic oxygen ($O_2$) and an oxygen radical ($O$). The oxygen radical may then bond with another $O_2$ molecule to form another ozone molecule.

The cycle of ozone being destroyed then created then destroyed again seems to be just another curious science fact. However, it is also critical for life on Earth. Each time an ozone molecule is broken apart by ultraviolet radiation, it absorbs that radiation, preventing it from reaching the Earth's surface where it would do substantial harm. This is a significant aspect of the ability of the ozone layer to protect life forms. Once the ozone molecule has been created, it continues to absorb UV radiation, but of a different kind. This UV radiation is in the 2800 to 3200 angstrom wavelength and is known as UVb. As long as the ozone layer absorbs UVb radiation, very little of it can reach us.

The ozone "story" is one that has been around for about 30 years and is presently made up of three parts: the good, the bad and the ugly. There is the" good" ozone found in the stratosphere which is 10 to 30 miles above the Earth's surface. This ozone functions as an ultraviolet radiation shield that allows for the existence of most life on Earth.

The "bad " is the fact that ozone also appears in the troposphere. The troposphere is from ground level
to 10 miles above the Earth. Ozone is toxic to life forms. Ozone causes breathing difficulties, headaches, fatigue and can aggravate respiratory problems. The "ugly" is the fact that the "good ozone" appears to be decreasing while the "bad ozone" is increasing.

**The Two Ozones**

Ozone occurs in two layers of the atmosphere. The layer surrounding the earth's surface is the troposphere. Here, ground level or "bad" ozone is an air pollutant that damages human health, vegetation, and many common materials. It is a key ingredient of urban smog. The troposphere extends to about 10 miles up where it meets the stratosphere. The stratospheric or "good" ozone layer extends upward from about 10 to 30 miles and protects life on earth from the sun's harmful ultraviolet rays (UV-b). Although ozone molecules play such a vital role in the atmosphere they are rare. In every million molecules of air fewer than ten are ozone. About 90 percent of the ozone resides in this layer. Ozone there plays a beneficial role by absorbing dangerous ultraviolet radiation from the sun.

**What Causes "Bad" Ozone?**

Motor vehicle exhaust and industrial emissions, gasoline vapors and chemical solvents are some of the major sources of NO\(_x\) and VOC (ozone precursors). Strong sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. Many urban areas tend to have high levels of "bad" ozone. Other areas are also subject to high ozone levels as winds carry NO\(_x\) emissions hundreds of miles away from their original sources. Ozone in the troposphere can contribute to greenhouse warming.

Ozone concentrations can vary from year to year. Changing weather patterns (especially the number of hot, sunny days), periods of air stagnation and other factors that contribute to ozone formation make long-term predictions difficult.

**How Does "Bad" Ozone Affect Human Health and the Environment?**

Repeated exposure to ozone pollution may cause permanent damage to the lungs. Even when ozone is present in low levels, inhaling it triggers a variety of health problems including chest pains, coughing, nausea, throat irritation, and congestion. It also can worsen bronchitis, heart disease, emphysema, and asthma, and reduce lung capacity.

Healthy people also experience difficulty in breathing when exposed to ozone pollution. Because ozone pollution usually forms in hot weather, anyone who spends time outdoors in the summer may be affected. Ozone is particularly dangerous to children, the elderly, outdoor workers and people exercising. Millions of Americans live in areas where the national ozone health standards are exceeded. Many areas with ozone problems have “Ozone Alert” periods where they recommend people stay indoors.

Ground-level ozone damages plant life and is responsible for ~500 million dollars in reduced crop production in the United States each year. It interferes with the ability of plants to produce and store food, making them more susceptible to disease, insects, other pollutants and harsh weather. "Bad"
ozone damages the foliage of trees and other plants, ruining the landscape of cities, national parks and forests, and recreation areas.

**What is Being Done About “Bad” Ozone?**

The Clean Air Act Amendments of 1990 required the EPA, states and cities implement programs to further reduce emissions of ozone precursors from sources such as cars, fuels, industrial facilities, power plants and consumer/commercial products. Power plants reduced emissions, cleaner cars and fuels are being developed, many gas stations now use special nozzles at the pumps to recapture gasoline vapors and vehicle inspection programs are being improved to reduce emissions.

**What Can You Do to Prevent “Bad” Ozone?**

- Keep your automobile well tuned and maintained.
- Carpool, use mass transit, walk, bicycle, and/or reduce driving, especially on hot summer days.
- Be careful not to spill gasoline when filling up your car or gasoline-powered lawn and garden equipment. During the summer fill your gas tank during the cooler evening hours to reduce vapor loss.
- Make sure your car's tires are properly inflated and your wheels are aligned.
- Participate in your local utility's energy conservation programs.
- Seal containers of household cleaners, workshop chemicals, solvents and garden chemicals to prevent VOC from evaporating into the air. Dispose of them properly.

**What is happening to the "Good" Ozone Layer?**

Ozone occurs naturally in the stratosphere and is produced and destroyed at a constant rate. But manmade chemicals are gradually destroying this “good” ozone. They include chlorofluorocarbons (CFCs), halons and other ozone depleting substances used in coolants, foaming agents, fire extinguishers and solvents. In 1974 Sherwood Roland and Mario Molina, scientists with the University of California, described how a group of non-reactive molecules, chlorofluorocarbons or CFCs, such as Freon, can become highly reactive when in the stratosphere. CFCs were produced on a mass scale and were used worldwide for refrigeration, foam production (i.e. Styrofoam) and a variety of industrial and manufacturing processes. These ozone-depleting substances degrade slowly and can remain intact for many years as they move through the troposphere until they reach the stratosphere. There they are broken down by the intensity of the sun's ultraviolet rays. Then they release chlorine and bromine molecules that destroy "good" ozone. One chlorine or bromine molecule can destroy 100,000 ozone molecules, causing ozone to disappear much faster than nature can replace it.

The journey from the Earth's surface to the stratosphere for a CFC molecule may take as long as 30 years. Once there, the non-reactive CFC molecule is struck by UV radiation. Just as this radiation breaks \( O_3 \) apart, it also breaks apart the CFC, releasing a chlorine atom. This chlorine atom combines with ozone to form \( ClO \) (chlorine monoxide) and \( O_2 \). Since the \( ClO \) molecule is unstable, it tends to break apart, releasing the chlorine atom to find another ozone molecule to destroy. Like the "Energizer Bunny," the little chlorine atom keeps on going and going, destroying ozone molecules.

It can take years for ozone depleting chemicals to reach the stratosphere. Even though we have reduced or eliminated the use of many CFCs their impact from years past is just starting to affect the ozone layer. Substances released into the air today will contribute to ozone destruction well into the future.
Roland and Molina's experiments demonstrated that the ozone layer could be harmed by CFCs, but there was insufficient data to prove that the ozone layer was actually being depleted. In the mid-1980s scientists found the evidence. Satellite observations indicate a worldwide thinning of the protective ozone layer. The most noticeable losses occur over the North and South Poles because ozone depletion accelerates in extremely cold weather conditions. The concentration of stratospheric ozone suffered a significant and unexpected decrease over Antarctica. By 1986, the "ozone hole" received national attention. Since the 1980s, ozone levels have continued to decrease to as much as 70% lower than those expected in Polar Regions.

How Does the Depletion of "Good" Ozone Affect Human Health and the Environment?

As the stratospheric ozone layer is depleted, higher UV-b levels reach the Earth's surface. Increased UV-b can lead to more cases of skin cancer, cataracts, and impaired immune systems. The number of cases is uncertain but estimates are for about 30,000 cases of non-melanoma skin cancers per year with every one percent decrease in the ozone layer. A United Nations Environmental Program report estimates that for every one percent decrease in stratospheric ozone, there would be an additional 1.7 million cases of cataracts each year worldwide. Damage to UV-b sensitive crops, such as soybeans, reduces yield. High altitude ozone depletion is suspected to cause decreases in phytoplankton, a plant that grows in the ocean. Phytoplankton is an important link in the marine food chain and, therefore, food populations could decline. Because plants "breathe in" carbon dioxide and "breathe out" oxygen, carbon dioxide levels in the air could also increase potentially contributing to global warming. Increased UV-b radiation can be instrumental in forming more ground level or "bad" ozone.

What is Being Done About the Depletion of Good Ozone?

After the publication by Rowland and Molina, a controversy developed about the use of CFCs in aerosol cans. The controversy resulted in a ban on
the use of CFCs as propellants for spray cans in the United States. The ban was a first step in the effort to save the stratospheric ozone.

It was almost ten years before the next step was taken. In March 1984, a non-binding international treaty was signed in Vienna, Austria. Known as the Vienna Convention, the treaty was a declaration by several countries to study the problem of ozone depletion and prepare options. The 1986 appearance of the Antarctic "ozone hole" spurred negotiations of a new treaty, the Montreal Protocol. Signed in 1987, the Montreal Protocol called for a gradual reduction in CFC production to 50% of previous levels; however, scientific evidence of the severity of the ozone problem continued to mount. The Montreal Protocol was to become effective in 1989. Revisions were made before it started. The London Revision (1989) of the Montreal Protocol called for the complete phase-out of CFC production by the year 2000. The United States signed each ozone treaty and has been a leader in implementing the treaties and conducting the research to support them. Currently, 160 countries participate in the Protocol. Efforts will result in recovery of the ozone layer in about 50 years. With the leadership of the industrialized nations and the participation of the international community, the London Revision treaty should bring chlorine levels in the stratosphere down to below present day levels. Unfortunately, this will not happen for another 50-100 years. Until that time, the full effects of the ozone depletion identified in the 1980s will continue to unfold.

In the United States, the U.S. Environmental Protection Agency (EPA) continues to establish regulations to phase out ozone depleting chemicals. The Clean Air Act required warning labels on all products containing CFCs or similar substances, prohibited nonessential ozone depleting products and prohibited the release of refrigerants used in car and home air conditioning units and appliances into the air.

**Good Ozone and You**

- Make sure technicians working on your car air conditioner, home air conditioner or refrigerator are certified by an EPA approved program to recover the refrigerant as required by law.
- Have your car and home air conditioner units and refrigerator checked for leaks. Repair leaky air conditioning units before refilling them. Convert the units to the newer more environmentally friendly refrigerants.
- Contact local authorities to properly dispose of refrigeration or air conditioning equipment.
- Protect yourself against sunburn. Minimize sun exposure during midday hours (10 am to 4 pm). Wear sunglasses, a hat with a wide brim and protective clothing with a tight weave. Use sunscreen with a sun protection factor (SPF) of at least 15. A SPF of 30 is better.

We live with ozone every day. It can protect life on earth or harm it. We have the power to influence ozone's impact by the way we live.
Write all answers in your notebook!

Ozone Questions

Matching:
Match the correct term to its definition. Write the correct answers in your notebook.

Chlorofluorocarbons          ozone layer          ultraviolet radiation

1. Layer in the stratosphere containing ozone, which absorbs ultraviolet radiation
2. Type of energy from the sun that can be harmful in large amounts
3. Chemicals used in some aerosol sprays, refrigerants, and some foam products

Write the word "true" or "false" in your notebook to indicate whether the statement is true or false.

4. The kind of oxygen we breathe can absorb ultraviolet radiation.
5. Scientists know exactly what is causing the ozone layer to disappear.
6. Chlorofluorocarbons are making the ozone layer thicker.
7. The ozone layer acts as a shield between ultraviolet radiation and us.
8. Thinning of the ozone layer has been found over Antarctica and the North Pole.
9. Ozone molecules destroy chlorofluorocarbon molecules.

Fill in the blank
You can find the words in your readings. Write the correct answers in your notebook.

\[ \text{__10__} (\text{O}_3) \text{ is a gas that forms in the atmosphere when 3 atoms of __11__ are combined.} \]

The ozone layer is actually a band of gas located in the __12__ that has especially high concentrations of ozone molecules. This band is found between __13__ and __14__ miles above the Earth's surface.

\[ \text{__15__ exhaust and industrial emissions, gasoline vapors, and chemical solvents are some of the major sources of __16__ and __17__, also known as ozone precursors. Strong __18__ and hot weather cause __19__ ozone to form in harmful concentrations in the air.} \]

But this "__20__" ozone is gradually being destroyed by manmade chemicals called __21__ (CFCs), halons, and other ozone depleting substances (used in coolants, foaming agents, fire extinguishers, and solvents).

One __22__ or bromine molecule can destroy __23__ ozone molecules, causing ozone to disappear much faster than nature can replace it.

Short Answer:
Write correct answers to these questions in your notebook

24. What is the difference between “good” and “bad” ozone?
25. Why is the stratospheric ozone layer important for life on Earth?
26. Why is the stratospheric ozone layer’s disappearance a problem?
27. How do CFC’s destroy stratospheric ozone?