OZONE

Contents

What is it, and why do we care about it?

Ozone is a relatively unstable molecule found in Earth's atmosphere. Most ozone is concentrated below a 30-mile (48-km) height. An ozone molecule is made up of three atoms of oxygen. Although it represents only a tiny fraction of the atmosphere, ozone is crucial for life on Earth.

Depending on where ozone resides, it can protect or harm life on Earth. High in the atmosphere about 15 miles (24 km) up ozone acts as a shield to protect Earth's surface from the sun's harmful ultraviolet radiation. Without this shield, we would be more susceptible to skin cancer, cataracts, and impaired immune systems. Closer to Earth, in the air we breathe, ozone is a harmful pollutant that causes damage to lung tissue and plants.

The amounts of “good” and “bad” ozone in the atmosphere depend on a balance between processes that create ozone and those that destroy it. An upset in the ozone balance can have serious consequences for life on Earth. Scientists are finding evidence that changes are occurring in ozone levels—the “bad” ozone is increasing in the air we breathe, and the “good” ozone is decreasing in our protective ozone shield. This article describes processes that regulate “good” ozone levels.

About 24 kilometers up in the atmosphere, in the region called the stratosphere, ozone is created and destroyed primarily by ultraviolet radiation. The air in the stratosphere is bombarded continuously with ultraviolet radiation from the sun. When high energy ultraviolet rays strike molecules of ordinary oxygen (O2), they split the molecule into two single oxygen atoms, known as atomic oxygen. A freed oxygen atom then can bump into an oxygen molecule

(O_2), and form a molecule of ozone (O_3).

The characteristic of ozone that makes it so valuable to us—its ability to absorb a range of ultraviolet rays—also causes its destruction. When an ozone molecule (O_3) absorbs even low energy ultraviolet radiation, it splits into an ordinary oxygen molecule (O_2) and a free oxygen atom (O). The free oxygen atom then may join up with an oxygen molecule to make another ozone molecule, or it may steal an oxygen atom from an ozone molecule to make two ordinary oxygen molecules. Some scientists call these processes of ozone production and destruction, initiated by ultraviolet radiation, the "Chapman Reactions."

Natural forces other than the Chapman Reactions also affect the concentration of ozone in the stratosphere. Because ozone is a highly unstable molecule, it reacts very easily, readily donating its "extra" oxygen molecule to nitrogen, hydrogen, and chlorine found in natural compounds. These elements always have existed in the stratosphere, released from sources such as soil, water vapor, and the oceans.

In addition, scientists are finding that ozone levels change periodically as part of regular natural cycles such as the changing seasons, sun cycles and winds. Moreover, volcanic eruptions may inject materials into the stratosphere that can destroy ozone.

Over the Earth's lifetime, natural processes have regulated the balance of ozone in the stratosphere. A simple way to understand the ozone balance is to think of a leaky bucket. As long as water is poured into the bucket at the same rate that water is leaking out, the amount of water in the bucket will remain the same. Likewise, as long as ozone is being created at the same rate that it is being destroyed, the total amount of ozone will remain the same.

In the past two decades, however, scientists have found evidence that human activities are disrupting the ozone balance. Human production of chlorine-containing chemicals such as chlorofluorocarbons (CFCs) has added an additional force that destroys ozone. CFCs are compounds made up of chlorine, fluorine and carbon bound together. Because they are such stable molecules, CFCs do not react easily with other chemicals in the lower atmosphere. One of the few forces that can break up CFC molecules is ultraviolet radiation. In the lower atmosphere, however, CFCs are protected from ultraviolet radiation by the ozone layer. CFC molecules thus are able to migrate intact up into the stratosphere. Although the CFC molecules are heavier than air, the mixing processes of the atmosphere carry them into the stratosphere.

Once in the stratosphere, however, the CFC molecules no longer are shielded from ultraviolet radiation by the ozone layer. Bombarded by the sun's ultraviolet energy, CFC molecules break up and release their chlorine atoms. The free chlorine atoms then can react with ozone molecules, taking one oxygen atom to form chlorine monoxide and leaving an ordinary oxygen molecule.

If each chlorine atom released from a CFC molecule destroyed only one ozone molecule, CFCs probably would pose very little threat to the ozone layer. However, when a chlorine monoxide molecule encounters a free atom of oxygen, the oxygen atom breaks up the chlorine monoxide, stealing the oxygen atom and releasing the chlorine atom back into the stratosphere to destroy more ozone. This reaction happens over and over again, allowing a single atom of chlorine to destroy many molecules of ozone.

Fortunately, chlorine atoms do not remain in the stratosphere forever. When a free chlorine atom reacts with gases such as methane (CH_4), it is bound up into a molecule of hydrogen chloride (HCL), which can be carried from the stratosphere into the troposphere, where it can be washed away by rain. Therefore, if humans stop putting CFCs and other ozone-destroying chemicals into the stratosphere, the ozone layer eventually may repair itself.

Ozone Depletion

The term “ozone depletion” means more than just the natural destruction of ozone, it means that ozone loss is exceeding ozone creation. Think again of the “leaky bucket.” Putting additional ozone- destroying compounds such as CFCs into the atmosphere is like causing the “bucket” of ozone to spring extra leaks. The extra leaks cause ozone to leak out at a faster rate—faster than ozone is being created. Consequently, the level of ozone protecting us from ultraviolet radiation decreases.

In the area over Antarctica, stratospheric clouds hold ice particles that are not present at warmer latitudes. Reactions occur on the surface of the ice particles that accelerate the ozone destruction caused by stratospheric chlorine. This phenomenon has caused documented decreases in ozone concentrations over Antarctica. In fact, ozone levels drop so low in spring in the southern hemisphere that scientists have observed what they call a “hole” in the ozone layer. In addition, scientists have observed declining concentrations of ozone over the whole globe. In the second half of 1992, for example, worldwide ozone levels were the lowest ever recorded.

Monitoring Ozone from Space

Since the 1920's, ozone has been measured from the ground. Scientists place instruments at locations around the globe to measure the amount of ultraviolet radiation getting through the atmosphere at each site. From these measurements, they calculate the concentration of ozone in the atmosphere above that location. These data, although useful in learning about ozone, are not able to provide an adequate picture of global ozone concentrations.

Contrary to the image created by the term "ozone layer," the amount and distribution of ozone molecules in the stratosphere vary greatly over the globe. Ozone molecules drift and swirl around the stratosphere in changing concentrations—much as clouds do in the satellite weather pictures you see on television news. Therefore, scientists observing ozone fluctuations over just one spot could not be confident that a change in local ozone levels meant an alteration in global ozone levels, or simply a fluctuation in the concentration over that particular spot. Satellites have given scientists the ability to overcome this problem because they provide a picture of what is happening simultaneously over the entire Earth.

Scientists now are confident that ozone is being depleted worldwide—partly due to human activities. However, scientists still need to determine how much of the loss is the result of human activity, and how much is the result of fluctuations in natural cycles.

Predicting Ozone Levels

If scientists can separate the human and natural causes of ozone depletion, they can formulate improved models for predicting ozone levels. The predictions of early models already have been used by policy makers to determine what can be done to reduce the ozone depletion caused by humans. For example, faced with the strong possibility that CFCs could cause serious damage to the ozone layer, policy makers from around the world in 1987 signed a treaty known as the Montreal Protocol. This treaty set strict limits on the production and use of CFCs. By 1990, the growing amount of scientific evidence against CFCs prompted diplomats to strengthen the requirements of the Montreal Protocol. The revised treaty called for a complete phase out of CFCs by the year 2000.

However, scientists agree that much remains to be learned about the interactions that affect ozone. To create accurate models, scientists must study simultaneously all of the factors affecting ozone creation and destruction. Moreover, they must study these factors from space continuously, over many years, and over the entire globe. NASA's Earth Observing System (EOS) will allow scientists to study ozone in just this way. The EOS series of satellites will carry a sophisticated group of instruments that will measure the interactions of the atmosphere that affect ozone. Building on more than 20 years of data gathered by previous NASA missions, these measurements will increase dramatically our knowledge of the chemistry and dynamics of the upper atmosphere and our understanding of how human activities are affecting Earth's protective ozone layer.

Source: NASA