3.4 Read

**What Causes the Smog in Los Angeles?**

If you were to take a walk in Los Angeles on a hot, sunny day, you might notice that the air looks orange. You might also have heard people use the word *smog* and talk about smog alerts. But you may not know exactly what smog is, where it comes from, and how it affects air quality.

![Smog in Los Angeles](image)

*Smog is a big problem for Los Angeles. Smog is also one of the few air pollutants you can see. In Los Angeles, it makes the air look orange.*

**How Does Smog Form?**

The term smog was first used to describe a combination of smoke and fog that occurred in London in the 1900s. The smog in London was caused by soot and other air pollutants that form during combustion of fuels, such as coal. In Los Angeles, smog is caused by a set of chemical reactions that require sunlight. When the Sun plays a role in chemical reactions, the reactions are called *photochemical* reactions. Smog formed in this way is known as photochemical smog.

This type of smog has four main requirements: oxygen ($O_2$), nitrogen oxides ($NO_x$), hydrocarbons, and *ultraviolet light (UV)*. You already know about oxygen and nitrogen oxides. A *hydrocarbon* is a compound containing only hydrogen and carbon atoms. Hydrocarbons can be simple molecules made up of just a few atoms, or they can be much more complicated with many atoms.
Many hydrocarbons are volatile organic compounds (VOC’s). You were introduced to VOC’s in *The Sickening Six* play. A VOC is a compound that evaporates at room temperature. Its vapors rise into the air. Gasoline is a VOC, as are solvents in paints, glues, and inks.

The other requirement, ultraviolet light, is part of the energy that comes from the Sun. The energy that travels to Earth from the Sun is carried by waves. There are different types of waves, including the visible light you can see, X-rays a doctor might use to see broken bones, and microwaves that are used to cook food and carry information. These waves are described by their lengths, known as wavelength, and the amount of energy they carry. When compared with other types of waves, ultraviolet light has short wavelengths and carries a lot of energy.

Smog forms through a cycle of reactions. In this cycle, sunlight hits nitrogen dioxide molecules in the atmosphere. When sunlight strikes the molecules, they split into nitrogen monoxide and single oxygen atoms. Then those oxygen atoms bond with oxygen molecules (O₂), making ozone molecules (O₃). Ozone is a particularly dangerous component of smog. The other chemicals needed for smog to form are nitrogen monoxide, nitrogen dioxide, and hydrocarbons. All these chemicals are products of combustion.

*For smog to form, four main ingredients are needed: oxygen (O₂), nitrogen oxides (NOₓ), hydrocarbons, and UV light from the Sun.*
Ozone: Good up High, Bad Nearby

You may have heard about something called the ozone hole where ozone high in the atmosphere is getting thinner and even disappearing. The ozone hole is caused by chemicals, such as CFC's (chlorofluorocarbons) in aerosol spray cans. These chemicals break down ozone into oxygen molecules and oxygen atoms. The ozone hole is a big problem. If you have heard that, then you will be wondering why ozone is a dangerous component of smog. The reason is that ozone high in the atmosphere is very different than ozone close to Earth's surface.

Normally, molecular oxygen is found as $O_2$ in the atmosphere. However, under the intense heat of the Sun, $O_2$ molecules can be broken into highly reactive oxygen atoms that then bond with other oxygen molecules, forming ozone, $O_3$. Ozone has very different properties than molecular oxygen.

In order to understand the role of ozone, you first need a brief description of the atmosphere. Earth's atmosphere consists of the gases that surround the planet—air. The atmosphere is described as five basic layers. Air becomes thinner and thinner as height, or altitude, increases within the layers.

Cars, trucks, power plants, and factories emit air pollution that forms ground-level ozone, a primary component of smog.
The first layer, which is closest to Earth’s surface, is known as the **troposphere**. Extending from the ground to about 10 km (6 mi), the troposphere is where weather occurs.

The next layer of the atmosphere is the **stratosphere**, which extends from about 10 km to 48 km (6 mi to 30 mi). Air in the stratosphere is about 1000 times thinner than it is at sea level. As a result, the highest altitudes that can be reached by jet aircrafts and weather balloons are found in this layer.

Above the stratosphere is the **mesosphere**. It extends to 85 km (53 mi) above Earth’s surface. Air in this layer is so thin that particles in air rarely collide with one another.

On top of the mesosphere is the **thermosphere**, which extends to between 500 and 1000 km (311 to 621 mi). The space shuttle orbits Earth in the thermosphere.

The highest layer of the atmosphere is called the **exosphere**. In this layer, the atmosphere gradually becomes outer space.

Ozone found up high in the stratosphere protects life on Earth from the Sun’s harmful ultraviolet (UV) rays. This ozone is known as “good ozone.” It occurs in very tiny amounts, about one to ten ozone molecules for every one million molecules of other gases (1–10 ppm). This ozone, often known as the ozone layer, was formed over 600 million years ago, before the first humans appeared.

Ozone that is closer to Earth, in the troposphere, however, is “bad ozone.” This ozone, called **ground ozone**, is formed from photochemical reactions that produce smog. This type of ozone can be found in the air you breathe and can do damage to your lungs and respiratory system. High levels of ground-level ozone can cause chest pain, coughing, sore throat, head congestion, and diseases of the lungs. Bad ozone also damages vegetation and ecosystems.
Stop and Think

1. The oxygen molecule ($O_2$) is a stable molecule because all the holes are filled and there are no bare bonds. Is ozone ($O_3$) a stable molecule? It might be helpful to use your atomic-model kit to build an ozone molecule.

2. Identify how good ozone and bad ozone are the same. Describe how they are different.

Primary and Secondary Pollutants

Smog is formed when pollutants already in the air react to form other pollutants. Scientists call the pollutants that are emitted directly into the air **primary pollutants**. Some primary pollutants you have studied include sulfur dioxide ($SO_2$), carbon monoxide ($CO$), and nitrogen monoxide ($NO$). They are emitted directly into the air from combustion engines.

Pollutants that are formed when primary pollutants react with each other are called **secondary pollutants**. Ground-level ozone is a secondary pollutant. So is nitrogen dioxide, the reddish gas that gives smog its reddish-orange color. The chart below shows some primary and secondary pollutants. Some you have already read about. Others you will read about later in the Unit.

<table>
<thead>
<tr>
<th>Primary Pollutants</th>
<th>Secondary Pollutants</th>
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</thead>
<tbody>
<tr>
<td>Sulfur dioxide ($SO_2$)</td>
<td>Sulfur trioxide ($SO_3$) and Acid rain</td>
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<tr>
<td>Nitrogen oxides ($NO_x$)</td>
<td>Nitrogen dioxide ($NO_2$), Ground-level ozone ($O_3$), and Acid rain</td>
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<tr>
<td>Carbon monoxide ($CO$)</td>
<td></td>
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<tr>
<td>Particulate matter, soot</td>
<td></td>
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<tr>
<td>Volatile organic compounds (VOC’s)</td>
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<tr>
<td>Toxic metals (mercury)</td>
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</tbody>
</table>

**primary pollutant:** pollutants formed directly from natural activities and human activities.

**secondary pollutant:** pollutants formed from primary pollutants.
Update the Project Board

Add what you now know about ozone and smog formation to the What are we learning? column of the Project Board. Include what you know about primary and secondary pollutants. Record your evidence in the What is our evidence? column. You may have identified some questions you need to answer to better understand the pollution in Los Angeles or to answer the Big Question. Add those to the What do we need to investigate? column.

What’s the Point?

Most of the atmospheric pollutants in Los Angeles are primary pollutants caused by combustion of fuels in cars, trucks, and other vehicles. A primary pollutant is a pollutant formed as a direct result of human or other activities. However, ozone ($\text{O}_3$) and nitrogen dioxide ($\text{NO}_2$), the major components of smog, are secondary pollutants. Secondary pollutants form in the air from primary pollutants. Ozone high up in the stratosphere protects life on Earth from the Sun’s UV radiation. However, ground ozone in the air is very harmful. It can cause chest pain, coughing, sore throat, head congestion, and diseases of the lungs. Bad ozone also damages vegetation and ecosystems.

Ozone is one harmful component of smog. It is generated in dangerous quantities when the nitrogen oxides ($\text{NO}$ and $\text{NO}_2$) react with volatile organic compounds (VOC’s) in sunlight. The nitrogen oxides are products of combustion. VOC’s result from the evaporation of fuel and chemical solvents. The chemical reactions that cause smog are photochemical reactions. This means they require sunlight. A greater amount of smog is produced when the weather is sunnier.

Groud ozone can make asthma worse.