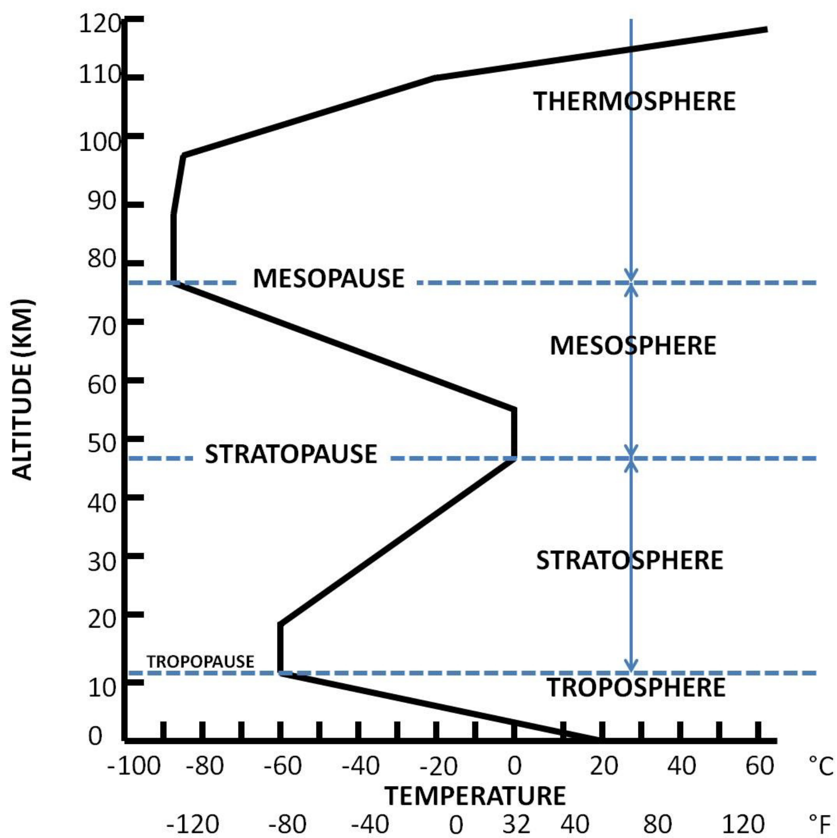
Chemistry in the Atmosphere

The most important gases to us are those in the **atmosphere** that surround Earth's surface. The principal components are N_2 and O_2, but many other important gases are also present. The table below shows the average composition of the atmosphere near sea level, with water vapor removed.

Component	**Percent**
N_2	78.084
O_2	20.948
Ar	0.934
CO_2	0.0345
Ne	0.001818
He	0.000524
CH_4	0.000168
Kr	0.000114
H_2	0.00005
NO	0.00005
Xe	0.0000087

Because of gravity, the composition of the atmosphere is not uniform. Heavier molecules tend to be near the surface and light molecules tend to migrate to higher altitudes. For convenience, we divide the atmosphere into several layers, as shown below.



The chemistry occurring in the higher levels of the atmosphere is mostly determined by the effects of high-energy radiation and particles from the sun. The upper atmosphere serves as an important shield to prevent this high-energy radiation from reaching the earth, where it would damage the relatively fragile molecules sustaining life. For example, ozone in the upper atmosphere helps prevent high-energy ultraviolet radiation from reaching the surface of the earth.

The chemistry in the troposphere is strongly influenced by human activities. Millions of tons of gases are released into the troposphere by humans, resulting in significant changes to the atmosphere. Severe **air pollution** is found around many large cities, and it is probable that long-range changes in our planet's weather are taking place.

The two main sources of pollution are transportation and the production of electricity. The combustion of petroleum products in vehicles produces CO, CO_2, NO, and NO_2, along with unburned molecules from petroleum. These chemicals are involved in reactions that are potentially irritating and harmful to living things.

Much of the chemistry of pollution revolves around the nitrogen oxides $[NO_x]$. At the high temperatures found in the engines of cars, N_2 and O_2 react to form NO. This NO is immediately oxidized in air to NO_2 which absorbs sunlight and breaks up into nitric oxide and free oxygen atoms:

$$NO_2(g) \rightarrow NO(g) + O(g)$$

Oxygen atoms are very reactive and can combine with CO to form *ozone*:

$$O(g) + O_2(g) \rightarrow O_3(g)$$

Ozone is also very reactive and can break up to form an energetically excited O_2 molecule and an energetically excited oxygen atom. This oxygen atom can then react with a water molecule to form two hydroxyl radicals:

$$O + H_2O \rightarrow 2OH$$

These hydroxyl radicals react with unburned hydrocarbons in the air to produce chemicals that irritate the eyes and harm the respiratory system. The end result of the above reactions is often referred to as **photochemical smog** — a mixture of a variety of irritating and harmful chemicals in the air.

Another major source of pollution results from burning coal to produce electricity. Most of the coal burned contains significant amounts of sulfur. When burned, sulfur produces sulfur dioxide:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

A further oxidation reaction occurs when sulfur dioxide is changed to sulfur trioxide in air:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

The production of sulfur trioxide is significant because it can combine with water droplets in the air to form sulfuric acid:

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Sulfuric acid is very corrosive to both living things and building materials. It is also one of the major components of **acid rain**. In many parts of the U.S. and Canada, acid rain has caused some freshwater lakes to become too acidic to support life.