

# Chapter 1 An Introduction to Air Pollution

## 1.1 An outline of the "Atmosphere"

### 1.1.1 Composition of the Atmosphere

The earth's "atmosphere" consists of an abundance of chemical elements. Its main constituents are nitrogen (volume ratio 78.1%) and oxygen (21.0%). Water vapor is also highly prevalent in the atmosphere though quantities vary. Other than this, existing in extremely minor quantities, are trace gases. Table 1.1.1 illustrates the chemical make-up of the atmosphere. Should wind shift in the atmosphere be weakly defined, gaseous components would likely undergo a diffusive separation. This is due to the fact that individual elements differ in mass from one another, resulting in heavier elements sinking to lower regions, while lighter elements would rise to regions higher in the atmosphere. However, in reality, due to the existence of wind conditions in the regions below the tropopause, 11 kilometers above ground, the elements are well mixed. The mixing ratio is relatively the same. However traces gases, excluding noble gases, are not equally distributed throughout the atmosphere by source or photochemical reaction within the atmosphere. But rather, their concentrations and distribution differ, effected by such factors as altitude, latitude, longitude, and time of year. Concentration levels also differ depending on place, such as in urban areas.

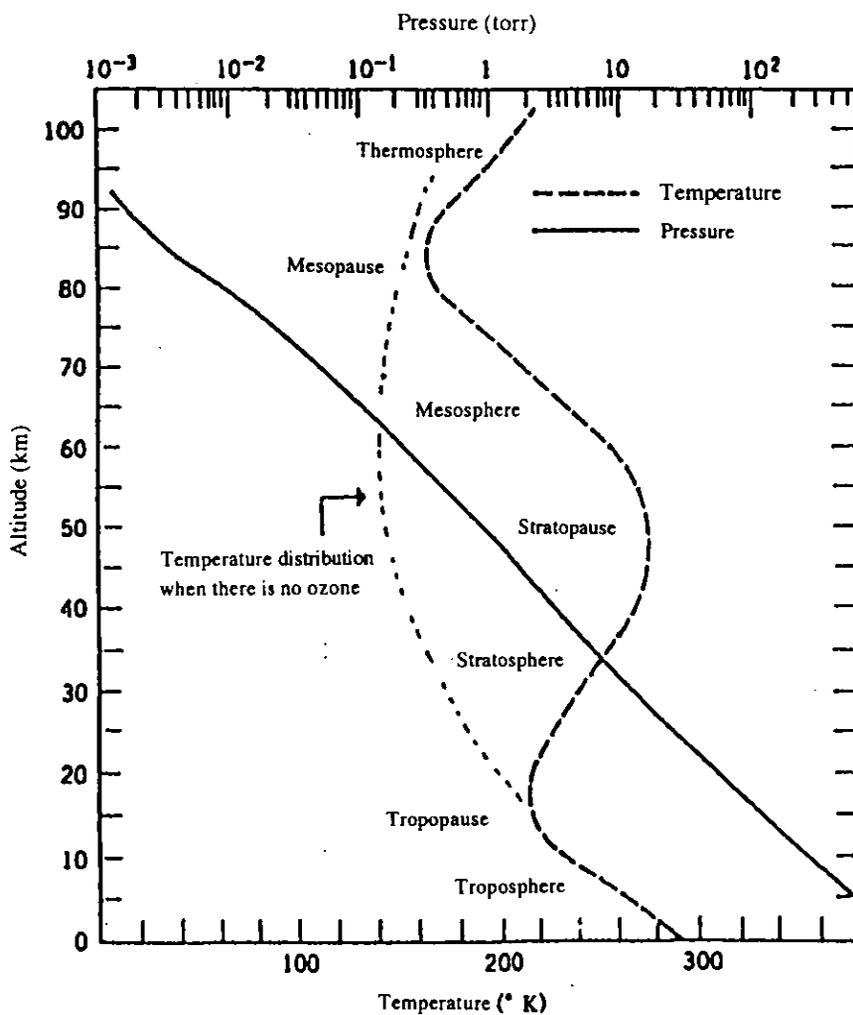
Table 1.1.1 Atmospheric Composition Around the Earth's Surface

Component	Molecular Formula	Molecular Weight	Existence Ratio (%)	
			Volume Ratio	Weight Ratio
Nitrogen molecules	N <sub>2</sub>	28.01	78.11	75.53
Oxygen molecules	O <sub>2</sub>	32.00	20.96	23.14
Argon	Ar	39.94	0.9343	1.280
Carbon dioxide gas	CO <sub>2</sub>	44.01	0.03	0.045
Carbon monoxide	CO	28.01	1 × 10 <sup>-3</sup>	1.2 × 10 <sup>-5</sup>
Neon	Ne	20.18	1.8 × 10 <sup>-3</sup>	1.2 × 10 <sup>-5</sup>
Helium	He	4.00	5.3 × 10 <sup>-4</sup>	7.3 × 10 <sup>-5</sup>
Methane	CH <sub>4</sub>	16.05	1.52 × 10 <sup>-4</sup>	8.4 × 10 <sup>-3</sup>
Krypton	Kr	83.7	1 × 10 <sup>-4</sup>	3 × 10 <sup>-4</sup>
Nitrous oxide	N <sub>2</sub> O	44.02	5 × 10 <sup>-5</sup>	8 × 10 <sup>-5</sup>
Hydrogen molecules	H <sub>2</sub>	2.02	5 × 10 <sup>-5</sup>	3 × 10 <sup>-6</sup>
Ozone	O <sub>3</sub>	48.0	2 × 10 <sup>-5</sup>	3 × 10 <sup>-6</sup>
Water vapor	H <sub>2</sub> O	18.02	variable	variable

### 1.1.2 Structure of the Atmosphere

The temperature of the atmosphere usually decreases in line with an increase in altitude. The major source of heat for these regions is solar radiation. Solar radiation is generated by the sun's rays which are initially absorbed into the earth's surface only to be reflected once again into the atmosphere. This warm air then rises to the upper

layers of the atmosphere. As illustrated in Fig. 1.1.1, air density (pressure) declines toward the upper layers of the atmosphere. As a result, as the air from the lower layers is carried up to higher regions, the energy contained by the elements in the atmosphere decreases due to the effects of adiabatic expansion, causing the temperature to drop. The atmospheric region or shell from the earth's surface to an altitude of 11 km is known as the troposphere. This comes from the fact that temperature distribution is determined by adiabatic expansion in this region of the atmosphere which has many convection currents. Above the troposphere, is the ozonosphere, in which solar radiation occurs. Ozone, plays an important part in the radiative balance of the atmosphere, preventing temperatures from declining by converting sunlight to heat and actually causing the temperature to rise gradually. Atmospheric stability is realized from the standpoint of temperature in regions where there convection currents do not occur, as warm air remains above cool air.



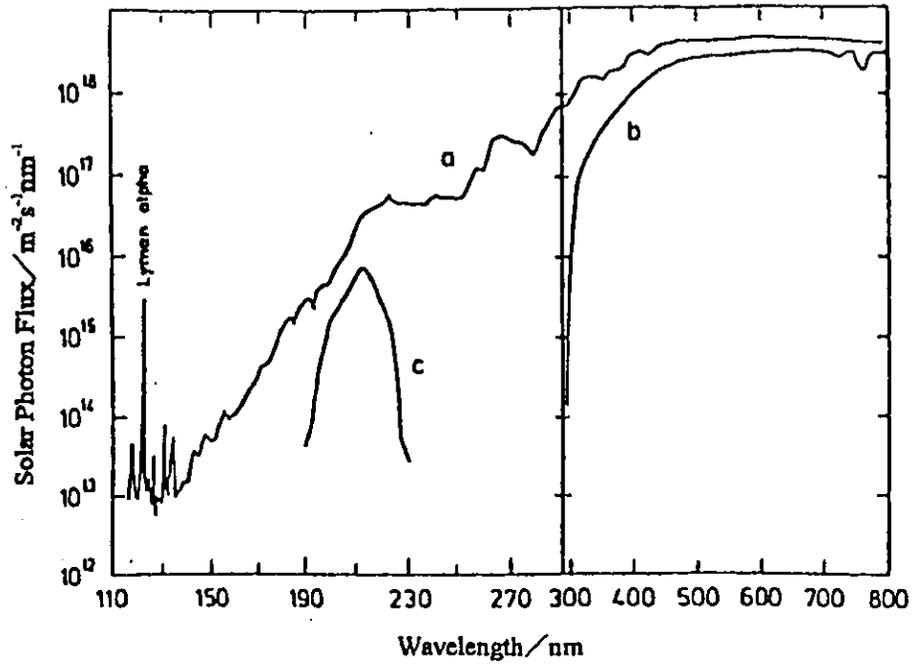
Note: temperature distributions predicted for when no ozone is present.

Fig. 1.1.1 Vertical structure of the atmosphere including atmospheric layer names, perpendicular distribution of temperatures and pressures

This atmospheric region is known as the stratosphere. The tropopause is the boundary between the troposphere and stratosphere where the temperature once again begins to elevate with altitude. Within the stratosphere, temperature is determined by radiation equilibrium, a balance between the ozone working to absorb the sun's UV radiation and cooling caused by infrared radiation. Furthermore, the fact that air density and ozone concentrations decrease at higher altitudes results in a decline in temperature. Temperatures reach maximum levels at an altitude of about 50 km. The altitude at which this temperature reaches its maximum, commonly defines the boundary of the stratosphere, and is the region known as the stratopause. The atmospheric shell above the stratopause is known as the mesosphere and is characterized by a temperature that typically declines with altitude. However, the temperature begins to increase once again at an altitude of nearly 80 km. Above this region is the shell known as the thermosphere. The mesopause exists between the mesosphere and the thermosphere. It is chiefly within the thermosphere that oxygen molecules absorb the sun's UV rays. This, along with the repeated process of photodissociation and recombination are what cause the sun's UV rays to be converted into heat and cause temperatures to rise. It is in this manner that the atmospheric structure is determined by physical and photochemical processes caused by the sun and related energy.

### 1.1.3 Solar Radiation

The sun emits a variety of electromagnetic waves from shortwaves (high energy), such as X-rays and UV rays, to longwaves (low energy) such as infrared, micro, or radio waves. Since the temperature of the sun's surface is 6,000 K, the energy distributed by solar radiation corresponds to that of a black-body at 6,000 K and the intensity maximum around the blue area at 480 nm. Fig. 1.1.2 illustrates the solar flux spectrum in the 120-800 nm wavelength region. The difference between (a) outside the earth's atmosphere and (b) at sea level, shows the absorption by gases in the atmosphere. In this absorption, the solar flux below 200 nm is absorbed mainly by the oxygen molecules and the flux between 200-300 nm is absorbed by the ozone in the stratosphere. The distribution of the solar flux changes depending upon the concentrations of ozone according to the altitude of the stratosphere. Fig. 1.1.2 (c) shows the solar photon flux at 30 km altitude to show the atmospheric window in the 180-220 nm wavelength region, where the valley between the absorption by oxygen below 200 nm and ozone around 250 nm. We can see that the composition of atmospheric trace gases and the structure of the atmosphere are controlled by the photochemical reactions due to solar radiation at 180-220 nm in the stratosphere and above 400 nm in the troposphere. Therefore, when considering the problems of the atmosphere, it is necessary to think of the physical movements in the atmosphere and the chemical (photochemical) reactions in the atmosphere. We recommend the reference materials listed below to those who wish to learn more about atmospheric physics and chemistry.



Note: (a) outside the earth atmosphere, (b) at sea level, and (c) at about 30km altitude to show the atmosphere window in the 185-215 nm wavelength region.

Fig.1.1.2 The solar flux spectrum in the 120-800nm wavelength region