Discussion Questions

- How do atmospheric scientists view the atmosphere?
- What gases are pollutants in the atmosphere?

The atmospheric chemistry studies the chemical composition of the natural atmosphere, the way gases, liquids, and solids in the atmosphere interact with each other and with the earth’s surface and associated biota, and how human activities may be changing the chemical and physical characteristics of the atmosphere. It is interesting to note that the 1995 Nobel Prize in Chemistry 1995 was awarded to the atmospheric scientists P. Crutzen, M. Molina and F. S. Rowland. For convenience of study, atmospheric scientists divide the atmosphere as if it consists of four layers. The division is mainly due to temperature variations as the altitude increases. The four layers according to the variation of temperature are.

- Ionosphere (Aurora) or Thermosphere
- Mesosphere
- Stratosphere
- Troposphere
Above 100 km is the thermosphere and ionosphere where the temperature increases from 200 K at 100 km to 500 K at 300 km. The temperature goes even higher as the altitude increases. Activity as the altitude decrease. In the outer space, most particles consist of single atoms, H, He, and O etc. At lower altitude (200 - 100 km), diatomic molecules N\(_2\), O\(_2\), NO etc are present. The ionosphere is full of electrically charged ions. The UV rays ionizes these gases. The major reactions are

In the ionosphere:

\[O + h\nu \rightarrow O^+ + e^- \text{(18.1.1)}\]

\[N + h\nu \rightarrow N^+ + e^- \text{(18.1.2)}\]

In the neutral thermosphere:
\[ N + O_2 \rightarrow NO + O \label{18.1.3} \]
\[ N + NO \rightarrow N_2 + O \label{18.1.4} \]
\[ O + O \rightarrow O_2 \label{18.1.5} \]

Beyond the neutral thermosphere is the ionosphere and exosphere. These layers are of course interesting for space explorations and environmental concerns and space sciences. The atmosphere in the outer space is more like a plasma than a gas. Below the thermosphere is the mesosphere (100 - 50 km) in which the temperature decreases as the altitude increase. In this region, OH, H, NO, HO₂, O₂, and O₃ are common, and the most prominent chemical reactions are:

\[ H_2O + h\nu \rightarrow OH + H \label{18.1.6} \]
\[ H_2O_2 + O \rightarrow OH + OH. \label{18.1.7} \]

Below the mesosphere is the **stratosphere**, in which the temperature increases as the altitude increase from 10 km to 50 km. In this region, the following reactions are common:

\[ NO_2 \rightarrow NO + O \label{18.1.8} \]
\[ N_2O \rightarrow N_2 + O \label{18.1.9} \]
\[ H_2 + O \rightarrow OH + H \label{18.1.10} \]
\[ CH_4 + O \rightarrow OH + CH_3 \label{18.1.11} \]

Air flow is horizontal in the stratosphere. A thin ozone layer in the upper stratosphere has a high concentration of ozone. This layer is primarily responsible for absorbing the ultraviolet radiation from the sun. The ozone is generated by these reactions:

\[ O_2 + h\nu \rightarrow O + O \label{18.1.12} \]
\[ O_2 + O \rightarrow O_3 \label{18.1.13} \]

The troposphere is where all weather takes place; it is the region of rising and falling packets of air. The air pressure at the top of the troposphere is only 10% of that at sea level (0.1 atmospheres). There is a thin buffer zone between the troposphere and the next layer called the tropopause.
Figure (PageIndex{2}): Space Shuttle Endeavour silhouetted against the atmosphere. The orange layer is the troposphere, the white layer is the stratosphere and the blue layer is the mesosphere.[1] (The shuttle is actually orbiting at an altitude of more than 320 km (200 mi), far above all three layers.) from NASA.

The major components in the region close to the surface of the Earth are N\(_2\) (78%), O\(_2\) (21%), Ar (1%) with variable amounts of H\(_2\)O, CO\(_2\), CH\(_4\), NO\(_2\), NO, CO, N\(_2\)O, and O\(_3\). The ozone concentration in this layer is low, about 8% of the total ozone in the atmosphere is in the troposphere.

What gases are pollutants in the atmosphere?

From the atmospheric science viewpoint, interactions of all gases among themselves and their interaction with the environmental elements are of interest. However, for identification purposes, we need to identify the gases produced by man-made process (industry).

Some of the gases due to human activities are:

- Carbon dioxide result from the excess burning of carbon-containing fuel.
- Carbon monoxide produced by automobiles. This orderless and colorless gas is very toxic.
- Ozone produced in the exhaust of internal combustion engine, and the variation of ozone concentration in the stratosphere.
- Nitrogen oxides such as NO, NO\(_2\), N\(_2\)O\(_4\); due to the production of NO in the internal combustion engine.
- Methane gas produced due to treatments of large amount of waste.
- Sulfur oxides produced in mining operation and in the combustion of sulfur containing fuel. Sulfur oxide causes the so called acid rain problem.
- Chlorofluorocarbons (CFC) are gases used as refrigerant. When disposed into the atmosphere, they cause the ozone concentration to decrease.

Water vapor is also considered a greenhouse gas, but it is also generated by nature continuously due to radiation from the Sun. Of course, when water vapor condense into a liquid, much energy is released in the exothermal process. Condensation of water vapor causes storms and many of the weather phenomena.
Questions

1. According to what is the atmosphere divided into 4 layers?
   
   Skill -
   Describe the structure of the atmosphere.

2. Which layer contains the most ozone?

   Skill - Describe all the details of ozone?

3. How thick is the troposphere?

   Discussion - At the top of the world highest mountain, ~10 km in altitude, the atmosphere is only 0.1 of that at sea level. This is the top of the troposphere.

4. What type of gas is present in the thermosphere?

   Skill - Explain the chemistry taken place in the thermosphere?

5. How is the ionosphere different from other layers?

   Discussion - The aurora is related to the ions in the atmosphere.

6. What causes the gas molecules in the ionosphere to ionize and become charged particles?

   Skill - Describe the chemistry in the ionosphere.

7. If ozone is a beneficial gas in the atmosphere, why is ozone also a gaseous pollutant?

   Discussion - Decomposition of ozone releases O, OOH, OH radicals and they are harmful to many living organisms.

8. Why are chlorofluorocarbons a gaseous pollutant?

   Discussion - Ozone in the stratosphere absorbs harmful UV C and UV B, which are harmful to humans and plants.

9. Why is warming up of the Earth a bad thing?

   Skill - Give your opinion please on an issue.

Solutions

1. The division is made according to patterns of temperature variation.

2. The stratosphere, between 15 and 50 km.

3. The troposphere ranges from 8 to 15 km.

4. A very dilute concentration of monoatomic gas.

5. The ionosphere contains high concentration of charged particles.

6. Radiation or high energy photons from the sun caused ionization of atoms.

7. Ozone is very reactive, causing harm to living organisms.
8. Because they catalyze the decomposition of ozone in the stratosphere.
9. Because we do not know what is the consequence in the future.

Learning Guide

- How is the atmosphere divided into layers? What are the names of the layers?
- Where is the ozone layer located in the atmosphere? What is the molecular structure of ozone? How is the ozone formed?

Contributors and Attributions

- Chung (Peter) Chieh (Professor Emeritus, Chemistry @ University of Waterloo)