FYI The Greenhouse Effect — Venus, Earth, and Mars

Greenhouse Gases

In the news, we often hear about **greenhouse gases**. These gases are made of molecules that can store considerable amounts of energy. The bonds holding a molecule's atoms together are not rigid; they can twist, lengthen, and shorten, allowing the atoms to move slightly. When a molecule absorbs energy, its atoms move more, storing the energy in the molecule's flexing bonds. In general, the more bonds a molecule has, the more energy it can store. The stored energy increases a substance's temperature.

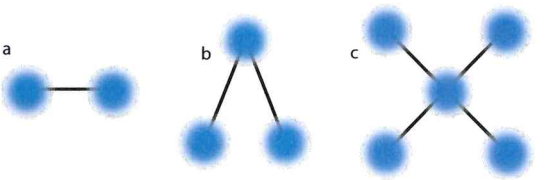

Figure 1-21: Diagrams showing the number of bonds and atoms in various atmospheric gases—(a) model of a nitrogen (N_2) or oxygen (O_2) molecule; (b) model of a carbon dioxide (CO_2), water (H_2O), or ozone (O_3) molecule; (c) model of a methane (CH_4) molecule

Any gas molecule with three or more atoms is a greenhouse gas. Thus, carbon dioxide (CO_2), water (H_2O), and ozone (O_3) are greenhouse gases. Each of them has two bonds holding their three atoms together (Figure 1-21b). When these molecules absorb energy, the atoms move more, flexing the bonds and storing the energy. The more bonds a gas molecule has, the more heat energy it can store. For example, methane (CH_4), with its four bonds (Figure 1-21c), holds 60 times as much heat energy as carbon dioxide does!

Compare this to how non-greenhouse gases, such as nitrogen (N_2) and oxygen (O_2), behave when absorbing energy. Nitrogen and oxygen have only one bond connecting the two atoms (Figure 1 - 21a). This bond cannot store as much energy. When nitrogen and oxygen are heated, the pair of atoms just spins end over end, with little energy being stored in the bond between them.

The Atmospheres of Venus and Mars

The atmospheres on both Mars and Venus are about 95% carbon dioxide, a greenhouse gas. One would think that both Mars and Venus would, therefore, be hot planets. However, the composition of an atmosphere is only one factor. The total amount of atmosphere a planet has and the albedo of that atmosphere are also important.

Venus has an extremely thick atmosphere, about 92 times thicker than that of Earth. This thick CO_2 atmosphere causes a strong greenhouse effect, absorbing and trapping heat on the planet. As a result, the average temperature on Venus is about 457 °C. This means that, on average, Venus is much hotter than Mercury, even though Mercury is closer to the sun.

This very high planetary temperature is even more remarkable when another aspect of Venus's atmosphere is considered. In its upper atmosphere, Venus has a layer of thick clouds. These clouds have a high albedo, reflecting over half of the sunlight that reaches them. What this means is that while Earth is farther from the sun than Venus is, Venus's surface actually receives less sunlight. As a result, without the runaway greenhouse effect of its atmosphere, the temperatures on the surface of Venus would actually be about the same as those on the surface of Earth.

Figure 1-22: Image of Venus with its thick, reflective layer of clouds

Mars has a thin atmosphere, about 170 times thinner than that of Earth. The thinness of this CO_2 atmosphere means that, despite the high concentration of greenhouse gas, the temperatures on Mars are low and vary widely.

The Atmosphere of Earth

In contrast, Earth's atmosphere is mostly made of non-greenhouse gases. Nitrogen and oxygen make up 99% of Earth's atmosphere. If these were greenhouse gases, Earth's average temperature would be several hundred degrees Celsius, instead of 15°C.

However, Earth's atmosphere is not devoid of greenhouse gases. For example, the greenhouse gas carbon dioxide is a small (0.04%) but vital part of Earth's atmosphere. There is carbon dioxide in Earth's atmosphere as part of natural processes, such as photosynthesis, but there is also carbon dioxide in the atmosphere because of human activities. In particular, the burning of fossil fuels such as gasoline, coal, and oil add carbon dioxide to the atmosphere. In this way, humans are increasing the ability of Earth's atmosphere to absorb and store energy. It is becoming increasingly clear that the increase in greenhouse gases and the subsequent warming of our planet is due to human activity. Some scientists think that global warming could occur due to a natural solar cycle, with the sun radiating more energy now than in the recent past. Regardless of the cause, the consequences of this heating worry many people. Recent trends include melting ice caps, rising sea levels, changing climates, decreased rainfall, and increased evaporation, which, in turn, adds more water vapor to the atmosphere and accelerates the heating.

Checking In

1. What features of a gas make it a "greenhouse gas"? Why?
2. Explain how the greenhouse effect warms a planet.

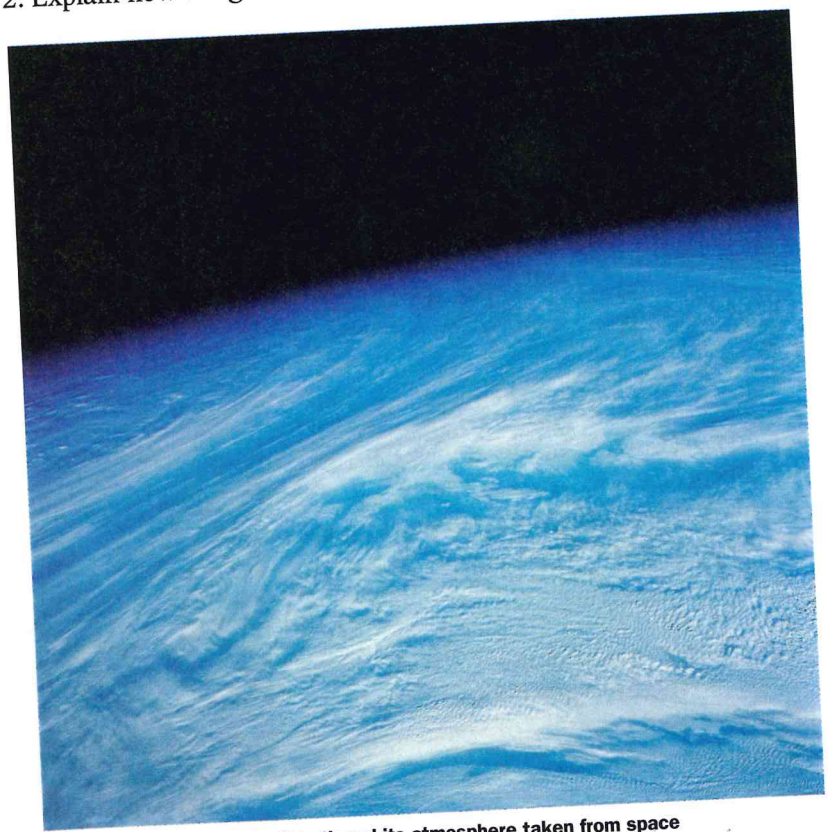

Figure 1-23: Photograph of Earth and its atmosphere taken from space