10.12: Natural Capital of the Atmosphere

As discussed in Section 1.4, Earth's natural capital is its ability to provide materials, protection, and conditions conducive to life including Earth's resources and its ecosystems. A large fraction of Earth's natural capital is in the atmosphere and includes materials, waste assimilative capacity and esthetics, largely determining the degree to which our surroundings are pleasant and conducive to our existence. The atmosphere's natural capital is discussed in this section.

A huge part of the atmosphere's natural capital is its ability to absorb and protect organisms from destructive ultraviolet and other short-wavelength cosmic and solar electromagnetic radiation which otherwise would make life on Earth impossible. The absorption of longer wavelength infrared radiation by which incoming solar energy is sent back into space leads to the second major protective function of the atmosphere, its ability to maintain surface temperature at a level at which life can thrive (see Figure 10.3).

The atmosphere is a source of essential raw materials, both for organisms and for industrial use and has major applications in the practice of green chemistry. Plants that provide the foundation of food chains within which all organisms thrive extract the carbon dioxide that they use to build biomass from the atmosphere. Animals and other organisms that perform oxic respiration obtain the molecular O_2 they require from the atmosphere. The refractory N_2 in the atmosphere is converted to biomass and protein nitrogen by bacteria growing in soil and water.

Humans also extract gases from the atmosphere for use in the anthrosphere. Adsorption, permeable membrane, and liquified air distillation processes are used to isolate nitrogen, oxygen, argon, and neon from air for use in the anthrosphere. Nitrogen extracted from air is first converted to ammonia, NH_3, then to industrial chemicals, fertilizers, and explosives. Boiling at a frigid-196°C, pure liquid nitrogen is the most widely used cryogenic liquid. Among its many uses are to preserve viable human embryos for embryo implantation to produce "test tube babies." As a generally unreactive gas, pure nitrogen is used as an inert atmosphere that prevents fires and other chemical reactions. Normally extracted from air along with pure nitrogen, pure oxygen has many industrial applications, such as in steel making, and is used for breathing by people with respiratory difficulties. Noble gas argon from the atmosphere is totally chemically inert and is used industrially, such as in specialized welding processes.

Green Oxygen and Nitrogen from the Air

Elemental oxygen and nitrogen are important commercial products extracted from air. Most commonly this is done by distilling cold liquid air, a process that can also produce noble gas neon, argon, and krypton, if desired. The initial step in air distillation is to compress air to about 7 times atmospheric pressure and cool it to remove water vapor and carbon dioxide. Further compression and cooling yields a liquid air product that can then be fractionally distilled to give relatively pure oxygen, nitrogen, and other gases. These can be stored as cold liquids or as the compressed gases.

Essentially pure oxygen has a number of applications, such as for breathing by people with pulmonary insufficiencies. Huge amounts are consumed in steel making. Pure nitrogen is used to provide inert atmospheres free of oxygen. Large quantities of liquid nitrogen are used in the science of **cryogenics** involving very low temperatures.

Emergency Oxygen

Emergency oxygen is required on aircraft that fly at high altitudes. The containers required to transport pure oxygen are too heavy to put on aircraft, so emergency oxygen is generated by a chemical process using a **chlorate candle**. This device contains sodium chlorate, $NaClO_3$, which decomposes when heated to generate oxygen gas:

$$2\,NaClO_3 \rightarrow 2\,NaCl + 3\,O_2 \tag{10.12.1}$$

Some of the oxygen generated reacts with a fuel, commonly elemental iron, mixed with the sodium chlorate,

$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3 \tag{10.12.2}$$

a heat-generating reaction that provides heat for the decomposition of the sodium chlorate. Chlorate candles can be stored for many years before being activated and still perform well. They are generally safe. However, chlorate candles improperly shipped in the baggage compartment of a ValuJet DC-9 aircraft caused an uncontrollable fire that brought the aircraft down in the Florida Everglades with the loss of all aboard in 1997.

As illustrated in Figure 8.1, the atmosphere is the conduit by which water is evaporated from oceans and carried over land where it falls as precipitation. This ability of the atmosphere is an important component of its natural capital and atmospheric conditions largely determine the quantity, quality, and distribution of water through the hydrologic cycle. Because of variations in atmospheric

conditions, the distribution of rainfall is irregular, with excess in some locations and times and deficiencies in others. Hot drought conditions that cause great hardship and even starvation, especially in parts of Africa, are the result of climate conditions in the atmosphere. Sulfur dioxide and nitrogen oxides emitted to the atmosphere as air pollutants produce sulfuric acid and nitric acid, respectively, polluting the hydrosphere with strong acids, killing fish fingerlings and harming vegetation.

Its ability to assimilate and process materials is an important part of the atmosphere's natural capital and a crucial component of nature's natural cycles. Transpiration of water from plant leaves is an important route for conveying water from soil to the atmosphere. Oxic respiration by humans and other organisms discharges carbon dioxide to the atmosphere as do forest fires and anthrospheric combustion processes. Photosynthetically produced elemental oxygen enters the atmosphere. Pollen and small particles such as smoke or fumes produced by anthrospheric processes enter the atmosphere and are washed out with rain or deposited on Earth's surface. Hydrocarbons and nitrogen oxides from combustion are eventually purged from the atmosphere, often with the intermediate formation of oxidants, aldehydes, and particles characteristic of photochemical smog pollution.

The atmosphere's contribution to esthetics is a major facet of its natural capital. Clear, clean air free of visibility-obscuring particles, acidic gases, and ozone that hinders breathing and irritates eyes has genuine value including its contribution to good health. Whereas the water that humans use can be purified from muddy, even polluted sources, air used for breathing must usually be taken as it comes. Humid, foggy air contaminated by acidic constituents and particles is unpleasant and even unhealthy to breathe as is air heated and dried to uncomfortable levels by greenhouse gas emissions.
