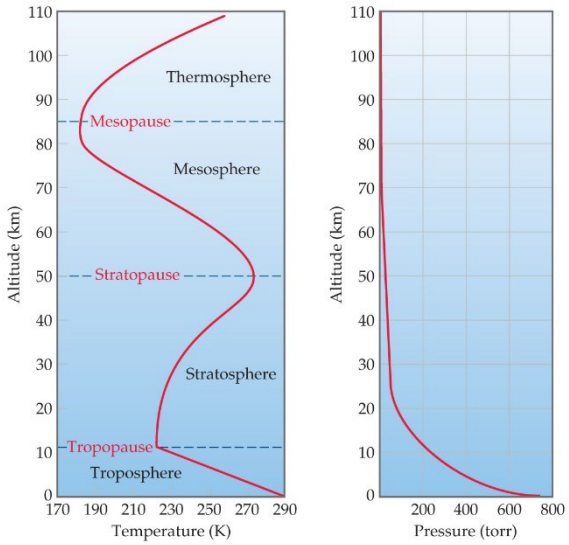
Chapter 18
Chemistry of the Environment

Review

Definitions:

- **Atmosphere:** The atmosphere consists of the troposphere, stratosphere (combined 99.9 mass %), mesosphere, and thermosphere.



- **Composition of the Atmosphere:** it is not uniform.

Table 18.1 The Major Components of Dry Air near Sea Level

Component*	Content (mole fraction)	Molar Mass (g/mol)
Nitrogen	0.78084	28.013
Oxygen	0.20948	31.998
Argon	0.00934	39.948
Carbon dioxide	0.000400	44.0099
Neon	0.00001818	20.183
Helium	0.00000524	4.003
Methane	0.000002	16.043
Krypton	0.00000114	83.80
Hydrogen	0.0000005	2.0159
Nitrous oxide	0.0000005	44.0128
Xenon	0.000000087	131.30

*Ozone, sulfur dioxide, nitrogen dioxide, ammonia, and carbon monoxide are present as trace gases in variable amounts.

- **Photochemical Reactions in the Atmosphere:**
  Photodissociation: The rupture of a chemical bond resulting from absorption of a photon by a molecule. Ions are not formed; radicals (having unpaired electrons) are often formed.

  Photoionization: occurs when a molecule in the upper atmosphere absorbs solar radiation and the absorbed energy causes an electron to be ejected from the molecule. The result is formation of a cation.

Table 18.3 Photoionization Reactions for Four Components of the Atmosphere

Process	Ionization Energy (kJ/mol)	λ_{max}(nm)
$N_2 + h\nu \longrightarrow N_2^+ + e^-$	1495	80.1
$O_2 + h\nu \longrightarrow O_2^+ + e^-$	1205	99.3
$O + h\nu \longrightarrow O^+ + e^-$	1313	91.2
$NO + h\nu \longrightarrow NO^+ + e^-$	890	134.5

- **Ozone:** Ozone in the upper atmosphere protects us from these harmful high-energy photons, which would otherwise penetrate to Earth's surface. It forms from reaction of molecular oxygen with the oxygen atoms produced in the upper atmosphere by photodissociation.

$$:\ddot{O} + O_2 \longrightarrow O_3^*$$

The * on O_3 denotes that the product contains an excess of energy, an energy-rich O_3* molecule can release its excess energy by colliding with another atom or molecule and transferring some of the excess energy to it.

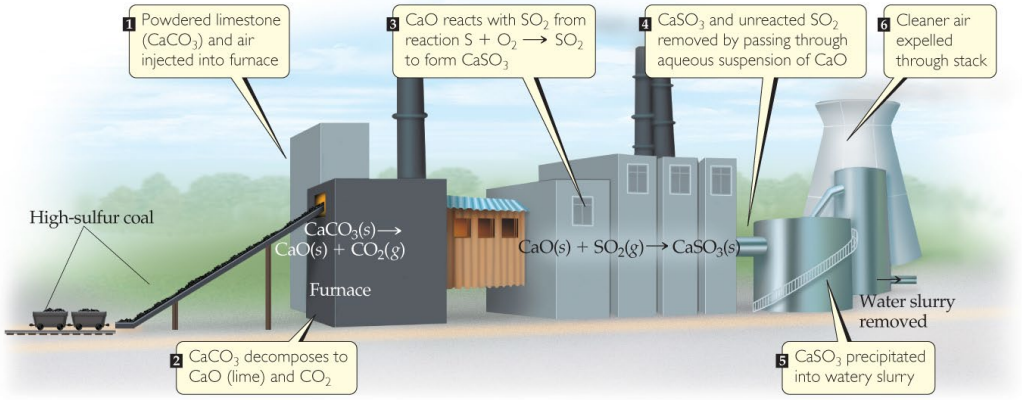
- **Ozone Depletion:** chlorine from chlorofluorocarbons (CFCs) may deplete the ozone layer in the upper atmosphere by chemical means.

$$Cl + O_3 \rightarrow ClO + O_2$$

- **Pollutant gases present in the "typical" urban environment:** SO_2 is regarded as the most serious health hazard among the pollutants on the list. It is a by-product of the burning of coal or oil.

Pollutant	Concentration (ppm)
Carbon monoxide	10
Hydrocarbons	3
Sulfur dioxide	0.08
Nitrogen oxides	0.05
Total oxidants (ozone and others)	0.02

- **Acid Rain:** Has a typical pH value of about 4. The presence of SO_2 in the atmosphere and the sulfuric acid it produces are primarily responsible for acid rain. (Nitrogen oxides also contribute to acid rain.)
- **A Chemical Method to Prevent SO_2 Emissions:** Powdered limestone ($CaCO_3$) can be added to the furnace of a power plant. It is converted to CaO, which reacts with SO_2 to make $CaSO_3$. Gases can pass through a suspension of CaO, with the same result.



- **Photochemical smog:** the pollution condition that occurs in certain urban environments when weather conditions produce a relatively stagnant air mass. Nitrogen oxides are primary components of smog.
- **The Greenhouse Effect:** The influence of H_2O, CO_2, and certain other atmospheric gases on Earth's temperature is called the greenhouse effect because in trapping infrared radiation these gases act much like the glass of a greenhouse. The gases themselves are called **greenhouse gases**.

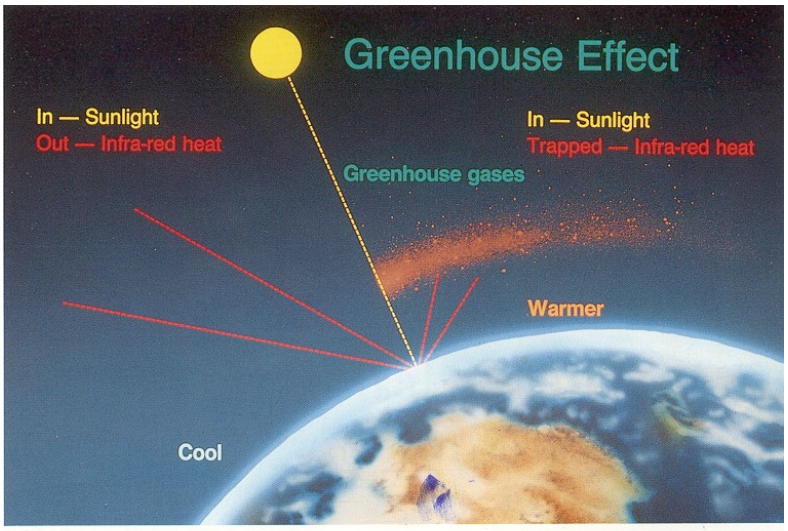
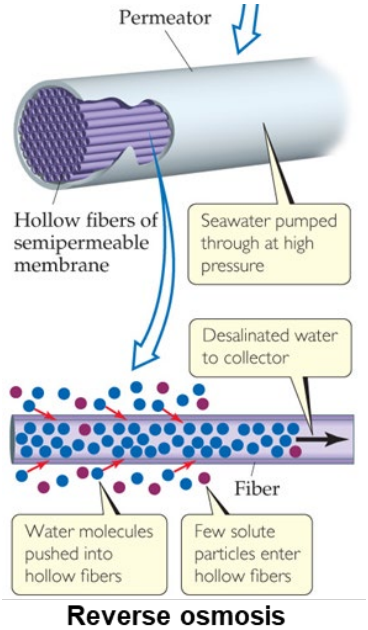


Figure I. *How the Greenhouse Effect works*

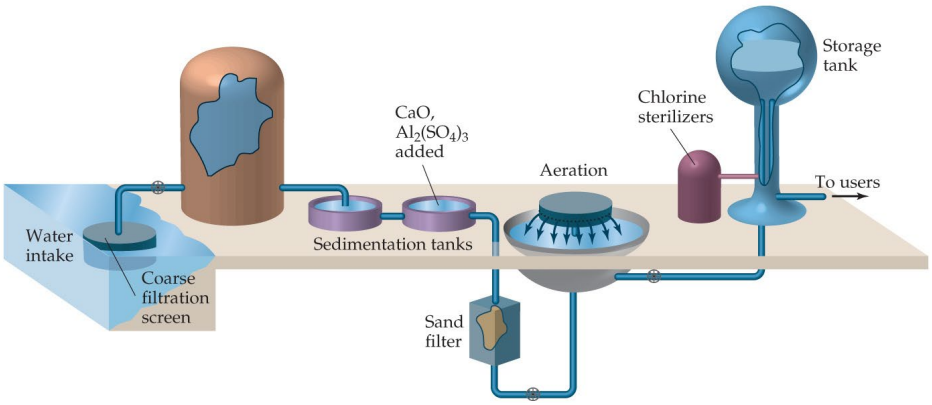
- **The Global Water Cycle:**
- **Salt Water:** Earth's Oceans and Seas. The world ocean contains 97.2% of all the water on Earth. The vast ocean contains many important compounds and minerals.
- **Freshwater and Groundwater:** Freshwater is the term used to denote natural waters that have low concentrations (less than 500 ppm) of dissolved salts and solids. All fresh water is only about 0.6% of water on the planet.
- **Desalination:** the removal of salts from seawater or brackish water to make it fit for human consumption. It may be accomplished by distillation or by reverse osmosis.
- **Reverse osmosis:** Water naturally flows through a semipermeable membrane from regions of low salt concentration to regions of high salt concentration. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, so that the water can be forced through a membrane in the opposite direction, concentrating the pure water.



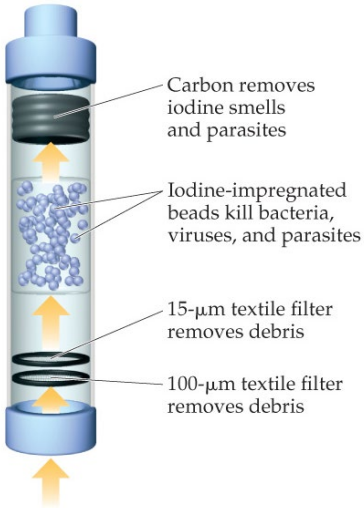
Reverse osmosis

- **Steps to purifying water for a municipal supply:**

1) CaO and $Al_2(SO_4)_3$ are added for the removal of very small particles.
2) Water is aerated to increase amount of dissolved oxygen and for oxidation of organic impurities.
3) Ozone or chlorine is used to disinfect the water.



- **Water Purification—LifeStraw**



- **Green Chemistry:** is an initiative that promotes the design and application of chemical products and processes that are compatible with human health and that preserve the environment.
- **Green Chemistry Principles:**

1. Prevention: It is better to prevent waste than to clean it up after it has been created.

2. Atom Economy: Methods to make chemical compounds should be designed to maximize the incorporation of all starting atoms into the final product.

3. Less Hazardous Chemical Syntheses: Wherever practical, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Design of Safer Chemicals: Chemical products should be designed to minimize toxicity and yet maintain their desired function.

5. Safer Solvents and Auxiliaries: Auxiliary substances (for example, solvents, separation agents, etc.) should be used as little as possible. Those that are used should be as nontoxic as possible.

6. Design for Energy Efficiency: Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, chemical reactions should be conducted at room temperature and pressure.

7. Use of Renewable Feedstocks: A raw material or feedstock should be renewable whenever technically and economically practical.

8. Reduction of Derivatives: Unnecessary derivatization (intermediate compound formation, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. Catalysis: Catalytic reagents (as selective as possible) improve product yields within a given time and with a lower energy cost compared to noncatalytic processes and are, therefore, preferred to noncatalytic alternatives.
10. Design for Degradation: The end products of chemical processing should break down at the end of their useful lives into innocuous degradation products that do not persist in the environment.
11. Real-Time Analysis for Pollution Prevention: Analytical methods need to be developed that allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Inherently Safer Chemistry for Accident Prevention: Reagents and solvents used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.