

CHAPTER 17

AIR POLLUTION

Important Concepts

1. About 99% of the earth's atmosphere is composed of only two gaseous elements: nitrogen and oxygen.
2. Gases and particles cycle through the atmosphere, with each substance having its own *residence time* in the atmosphere. For example, carbon dioxide, with a normal concentration of about 350 ppm, has a residence time of only four years, whereas inert gases such as argon have virtually infinite residence times.
3. Most *air pollutants* are gases or particulates. The principal gaseous pollutants are oxides of carbon, nitrogen, and sulfur. *Particulates* include soot, smoke, and ash produced by the combustion of fuels and the burning of vegetation. Particulates are also produced by natural processes such as volcanic eruptions, forest fires, wind erosion, and salt spray off the ocean surface. Residence times of particulates are relatively short.
4. The principal anthropogenic carbon gases are carbon dioxide and carbon monoxide. Increased carbon dioxide levels in the atmosphere enhance the greenhouse effect. Carbon monoxide is an end product of the incomplete combustion of carbon-bearing materials, especially fossil fuels, and is extremely toxic to human beings and animals.
5. The principal sulfur gas is sulfur dioxide, most of which is produced by the combustion of coal and petroleum. Sulfur dioxide reacts with water vapor in the atmosphere to produce sulfuric acid, which leaves the atmosphere in the form of *acid rain*.
6. The principal nitrogen gases are nitrogen monoxide and nitrogen dioxide, which are produced by combustion of all kinds, especially by combustion engines used in automobiles. Nitrogen dioxide reacts with water vapor to produce nitric acid. In the presence of sunlight, nitrogen dioxide molecules break up into nitrogen monoxide molecules and free oxygen atoms (O). These free oxygen atoms combine with molecular oxygen (O₂) to produce *ozone* (O₃), a key component of *photochemical smog*.
7. The presence of ozone in the upper atmosphere shields life on the earth's surface from the damaging effects of ultraviolet radiation. Recent studies reveal decreasing ozone levels within the upper atmosphere, and the depletion has been ascribed to reactive chlorine compounds derived from anthropogenic chlorofluorocarbons (CFCs) released to the atmosphere. A worldwide effort to eliminate the use of CFCs is in progress.
8. Acid rain is rain that is more acidic than normal. Although all precipitation is naturally slightly acidic, anthropogenic gases such as sulfur dioxide and nitrogen oxides form sulfuric acid and nitric acid, respectively, and make the rainwater even more acidic.
9. A frequent culprit for severe air pollution is *thermal inversion* — a temperature increase with altitude in the lower atmosphere — that creates a condition of stagnant air and traps the air pollutants.
10. The fundamental step necessary for controlling air pollution is to reduce the pollutants at their source. Some specific control methods include the use of filters and scrubbers for removing particulates and sulfur gases, high enough temperatures for complete combustion of carbon, and catalytic converters in automobiles to reduce the emission of harmful exhaust gases. The best solution to most air pollution problems may be a significant reduction in the consumption of fossil fuels. EPA-mandated reduction in the lead content of gasoline has already led to a sharp decline in the concentration of lead in the atmosphere.
11. The air quality level in the United States is described using an arbitrary scale based on the *Pollution Standard Index* (PSI).

Key Terms

acid rain	ozone
carbon gases	particulates
catalytic converter	photochemical smog
chlorofluorocarbons (CFCs)	photosynthesis
Clean Air Act	Pollution Standard Index
global carbon cycle	sulfur gases
greenhouse effect	thermal inversion
nitrogen gases	ultraviolet radiation

Multiple Choice

1. The most abundant gaseous element in the atmosphere is
 - a. oxygen.
 - b. carbon dioxide.
 - c. nitrogen.
 - d. argon.
2. Which of the following elements has the longest estimated residence time in the atmosphere?
 - a. helium
 - b. nitrogen
 - c. oxygen
 - d. carbon
3. The principal gaseous pollutants are oxides of all of the following elements except
 - a. carbon.
 - b. nitrogen.
 - c. sulfur.
 - d. lead.
4. In the United States, the greatest source of air pollutants is
 - a. electrical utilities.
 - b. transportation.
 - c. waste disposal.
 - d. residential.
5. The atmospheric gas that enhances the greenhouse effect heating of the atmosphere is
 - a. ozone.
 - b. carbon dioxide.
 - c. carbon monoxide.
 - d. sulfur dioxide.
6. The single largest source of carbon monoxide in the atmosphere is
 - a. volcanic eruptions.
 - b. the combustion of coal.
 - c. incinerators.
 - d. the automobile.

7. The principal factors in the formation of photochemical smog are high concentrations of nitrogen oxides and
 - a. strong sunlight.
 - b. high relative humidity.
 - c. high levels of carbon monoxide.
 - d. reduced precipitation.

8. In the atmosphere, sulfur dioxide combines with water vapor and oxygen to form
 - a. ozone.
 - b. smog.
 - c. sulfuric acid.
 - d. chlorofluorocarbons.

9. The substance in the upper atmosphere that absorbs harmful ultraviolet radiation is
 - a. ozone.
 - b. radon.
 - c. chlorofluorocarbon.
 - d. nitrogen dioxide.

10. An "ozone hole" first appeared over
 - a. North America.
 - b. Antarctica.
 - c. Europe.
 - d. Africa.

11. Atmospheric lead concentrations declined between 1975 and 1982 in response to
 - a. decreased volcanic activity.
 - b. reduced levels of lead in lead-based paints.
 - c. reductions in the lead content of gasoline.
 - d. reductions in the lead content of smokestack emissions.

12. Acid rain would have a pH value
 - a. higher than 14.
 - b. between 7 and 14.
 - c. of exactly 7.
 - d. lower than 7.

13. Which of the following negative impacts is not attributable to acid rain?
 - a. stunting of plants
 - b. destruction of the ozone layer
 - c. contamination of water supplies
 - d. leaching of toxic metals from soils

14. The indoor pollutant released by blown-in foam insulation is
 - a. ozone.
 - b. asbestos.
 - c. radon.
 - d. formaldehyde.

15. Pollution can affect weather conditions in which of the following ways?
- making rain more acidic
 - reducing visibility
 - modifying air temperature
 - All of the above are correct.
16. Which of the following methods is used to remove sulfur gases from coal-fired plant emissions?
- wet chemical scrubbing
 - catalytic converters
 - filters
 - lowering of combustion temperatures
17. The use of catalytic converters to reduce automobile emissions can actually increase the emissions of nitrogen oxides and
- ozone.
 - sulfuric acid.
 - carbon dioxide.
 - carbon monoxide.
18. A Pollutant Standards Index (PSI) rating of 200 to 300 could be described as
- moderate.
 - unhealthful.
 - very unhealthful.
 - hazardous.
19. Which of the following air pollutants has not shown a substantial reduction despite the imposition of air-quality and emissions standards by the Environmental Protection Agency?
- lead
 - nitrogen dioxide
 - carbon monoxide
 - sulfur dioxide
20. Annual per capita consumption of gasoline is highest in
- Sweden.
 - West Germany.
 - Japan.
 - the United States.

Fill In the Blanks

- The element _____ makes up about 23% of the atmosphere.
- The compound _____ is removed from the atmosphere during photosynthesis and by solution in the oceans.
- _____ is an invisible, odorless, and colorless gas that is toxic to animals because it replaces oxygen in the blood hemoglobin.
- An _____ molecule is composed of three oxygen atoms.

5. In the early 1970s, the Environmental Protection Agency began mandating reductions in the _____ content of gasoline.
6. _____ is rain whose pH value is lower than normal pH of surface water (pH = 7).
7. _____ is an invisible, odorless, colorless, and tasteless radioactive gas that can contribute to air pollution.
8. A _____ is an atmospheric condition in which air temperature increases with altitude rather than decreases.
9. _____ remove particulates from the air by using high voltages to charge the particulates, which are then attracted to and caught on charged plates.
10. A _____ uses a catalyst to enhance the combustion of the hydrocarbons and carbon monoxide in automobile exhaust to water and carbon dioxide.

True or False

Indicate whether the following statements are true or false. If false, correct the statement to make it true.

- ____ 1. Anthropogenic particulates comprise the majority of particulates in the atmosphere.
- ____ 2. Natural geochemical processes maintain the atmospheric carbon dioxide concentration at a constant level.
- ____ 3. Transportation is the major source of anthropogenic carbon monoxide in the atmosphere.
- ____ 4. The majority of the sulfur dioxide released into the atmosphere by human activities comes from automobile exhaust.
- ____ 5. Nitrogen dioxide reacts with water vapor in the atmosphere to produce nitric acid.
- ____ 6. Ozone levels in the upper atmosphere over the middle latitudes in the Northern Hemisphere have dropped by 1.7 to 3%.
- ____ 7. The granitic soils of the northeastern United States may account for much of the region's acidic lakes and streams.
- ____ 8. A thermal inversion triggered the severe air pollution event that affected Donora, Pennsylvania in 1948.

- _____ 9. Particulate pollutants in the atmosphere tend to inhibit the formation of rain, snow, and other forms of precipitation.
- _____ 10. One drawback to the use of filters to remove particulates is that filters cannot be used with very hot gases.

Review Questions

1. Draw a sketch, with adequate explanation, illustrating the geochemical cycle of carbon dioxide.
2. Explain the potential hazardous effects of the two carbon gases, carbon monoxide and carbon dioxide.
3. What is photochemical smog and how is it produced? Explain how thermal inversion may accentuate the problem.
4. Scientists have discovered an “ozone hole” over Antarctica. What is it and why is it a matter of concern? What steps are being taken to avoid this problem in the future?
5. What are the atmospheric pollutants that are responsible for acid rain, and how does each contribute to the problem? What are the likely adverse environmental impacts of acid rain?
6. Explain the EPA method of public reporting of air quality in a given area (see table 17.2).
7. Why is the abundance of automobiles believed to be the major cause of air pollution in many U.S. cities?
8. Why is radon gas in indoor air considered to be a health risk? What preventive measures should be taken by home owners to minimize this risk?

Surfing the Net

Information on acid rain (Clean Air Market Programs, U.S. Environmental Protection Agency):

<<http://www.epa.gov/airmarkets/>>

Selected U.S.G.S. publications on acid rain, radon gas, and water use in the United States (U.S. Geological Survey):

<<http://pubs.usgs.gov/gip/acidrain/>>

All about ozone depletion (U.S. Environmental Protection Agency):

<<http://www.epa.gov/docs/ozone/science/>>

Global Change Master Directory with many links (NASA):

<<http://gcmd.gsfc.nasa.gov/>>

Overview of National Air Pollutant Emission Trends, 1900-1998 (U.S. Environmental Protection Agency):

<<http://www.epa.gov/ttn/chief/trends/trends98.browse.html>>

Annual National Air Quality and Emissions Trend Report for 1998 (U.S. Environmental Protection Agency):

<<http://www.epa.gov/oar/aqtrnd98/>>

CHAPTER 17 ANSWER KEY

Multiple Choice

- | | | | |
|--------------------|-------|-------|-------|
| 1. c | 6. d | 11. c | 16. a |
| 2. a (table 17.1) | 7. a | 12. d | 17. b |
| 3. d | 8. c | 13. b | 18. c |
| 4. b (figure 17.2) | 9. a | 14. d | 19. b |
| 5. b | 10. b | 15. d | 20. d |

Fill In the Blanks

- | | |
|--------------------|--------------------------------|
| 1. oxygen | 6. Acid rain |
| 2. carbon dioxide | 7. Radon |
| 3. Carbon monoxide | 8. thermal inversion |
| 4. ozone | 9. Electrostatic precipitators |
| 5. lead | 10. catalytic converter |

True or False

1. False. Anthropogenic particulates account for less than 10% of the natural particulate air pollution.
2. False. Atmospheric carbon dioxide levels have increased more than 15% in the last century, and an estimated 30 billion tons of anthropogenic carbon dioxide are added to the atmosphere each year.
3. True
4. False. The bulk of the sulfur dioxide released into the atmosphere by human activities comes from the combustion of coal.
5. True
6. True
7. True
8. True
9. False. Particulate pollutants can enhance precipitation by providing nuclei on which water vapor can condense.
10. True