ANSWERS TO END-OF-CHAPTER QUESTIONS

CHAPTER 2: THE AIR WE BREATHE

Emphasizing Essentials

1. Answer:

a. $\frac{0.5\text{ L}}{1\text{ breath}} \times \frac{10\text{ breaths}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} \times 7.5\text{ hr} = 2.,250\text{ L}$

b. Possibilities include burning less (wood, vegetation, cooking fuels, gasoline, incense), using products that pollute less (low-emission paints), and using motor-less appliances and tools (hand lawnmower, egg beater, broom, rake)

2. Answer:

a. Rn < CO < CO_2 < Ar < O_2 < N_2
b. CO and CO_2
c. CO. By the time this book is in print, CO_2 may be regulated as well.
d. Rn (radon) and Ar (argon)

3. Answer:

Examples of particulate matter found in air include dust, soot, dirt, microscopic droplets of liquid, bacteria, and viruses. $PM_{2.5}$ and PM_{10} differ in size. The former has particles 2.5 μm or less in diameter; the latter 10μm or less. The smaller particles are more damaging to human health.

4. Answer:

a. $0.934\text{ parts per hundred} \times \frac{1{,}000{,}000\text{ parts per million}}{100\text{ parts per hundred}} = 9340\text{ parts per million}$

(Move the decimal 4 places to the right.)

b. $2\text{ ppm} \times \frac{100\text{ parts per hundred}}{1{,}000{,}000\text{ ppm}} = 0.0002\text{ parts per hundred or } 0.0002\%$

(Move the decimal 4 places to the left.)
20 ppm is equivalent to 0.0020%. 50 ppm is equivalent to 0.0050%.

c. $8{,}500\text{ ppm} \times \frac{100\text{ parts per hundred}}{1{,}000{,}000\text{ ppm}} = 0.85\text{ parts per hundred or } 0.85\%$

Be careful not to confuse the absolute humidity calculated in this problem with relative humidity, which is the amount of water vapor in the air compared to the maximum possible amount of water vapor that the air can hold at a particular temperature. For example, in a rainforest, the relative humidity is usually between 75 and 95%.

d. 8 ppm is 0.0008% (move the decimal 4 places to the left).

5. Answer:

a. The chemical formula tells the elements present in a compound and the atomic ratio of the elements.

b. Xe (xenon), N_2O (dinitrogen oxide or nitrous oxide), CH_4 (methane)

6. Answer:

a. Hydrocarbons are compounds that contain only the elements hydrogen and carbon.

b. ethane (C_2H_6), propane (C_3H_8), pentane (C_5H_{12}), hexane (C_6H_{14}), octane (C_8H_{18})

c. Answers will vary.

7. Answer:

The majority of our air is composed of nitrogen, oxygen, and argon, but the air is made up of other molecules in very small concentrations (on the order of 1 molecule in 100 or less). Examples of a trace substance found in air will vary, but the molecule responsible for the fragrance of a flower or fresh baking cookies are examples.

8. Answer:

Nitrogen is 78.0% of the air, meaning that out of 100 air particles, 78 of them are nitrogen molecules.

$$500\,\text{air particles} \times \frac{78\,\text{nitrogen molecules}}{100\,\text{air particles}} = 390\,\text{nitrogen molecules}$$

Oxygen is 21.0% of the air, meaning that out of 100 air particles, 21 of them are oxygen molecules.

$$500\,\text{air particles} \times \frac{21\,\text{oxygen molecules}}{100\,\text{air particles}} = 105\,\text{oxygen molecules}$$

Argon is 0.9% of the air, meaning that out of 100 air particles, 0.9 of them are argon atoms.

$$500\,\text{air particles} \times \frac{0.9\,\text{argon atoms}}{100\,\text{air particles}} = 4.5\,\text{argon atoms (or between } 4 - 5\,\text{argon atoms)}$$

9. Answer:

a. Each side of the equation has 6 C, 16 H, and 14 O.

b. Each side of the equation has 16 C, 36 H, and 50 O.

10. Answer:

a. Yes, the mass of the reactants equals the mass of the products. The Law of Conservation of Mass applies.

b. No, the numbers of molecules are not the same (four reactant molecules vs. two product molecules).

c. Yes, the numbers of each type of atom present as reactants and products are the same.

11. Answer:

a. $N_2(g) + O_2(g) \longrightarrow 2\ NO(g)$ (occurs at high temperature)

b. $O_3(g) \longrightarrow O_2(g) + O(g)$ (occurs in the presence of UV light)

c. $2\ S(s) + 3\ O_2(g) \longrightarrow 2\ SO_3(g)$

12. Answer:

a. $C_3H_8(g) + 5\ O_2(g) \longrightarrow 3\ CO_2(g) + 4\ H_2O(g)$

b. $2\ C_4H_{10}(g) + 13\ O_2(g) \longrightarrow 8\ CO_2(g) + 10\ H_2O(g)$

c. $2\ C_3H_8(g) + 7\ O_2(g) \longrightarrow 6\ CO(g) + 8\ H_2O(g)$

$2\ C_4H_{10}(g) + 9\ O_2(g) \longrightarrow 8\ CO(g) + 10\ H_2O(g)$

13. Answer:

a. $2\ C_2H_6(g) + 3\ O_2(g) \longrightarrow 4\ C(s) + 6\ H_2O(g)$

b. $2\ C_2H_6(g) + 5\ O_2(g) \longrightarrow 4\ CO(g) + 6\ H_2O(g)$

c. $2\ C_2H_6(g) + 7\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O(g)$

d. The balanced equations show that complete combustion requires the highest ratio of oxygen to ethane (7:2). If a 5:2 ratio is present, carbon monoxide is formed instead of carbon dioxide. If only a 3:2 ratio is available, then carbon (soot and particulate matter) is formed. Note: With less oxygen, the products are likely to be mixed, rather than pure CO or pure soot.

14. Answer:

A mixture is a substance composed of many different components, like the air we breathe. Examples will vary, but one mixture is lemonade. It is made by stirring together lemon juice, sugar, and water. Another example is sand from the beach. If you look closely, it is made up of a variety of different chemical components in addition to seaweed, shells, etc.

15. Answer:

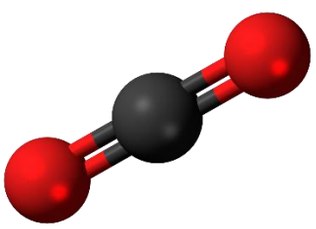
In respiration, inhaled oxygen reacts with sugar in your body to produce carbon dioxide and water vapor to produce energy. Therefore, exhaled air has a decreased percentage of oxygen, and increased percentage of carbon dioxide. Oxygen is used to metabolize the food that we eat.

16. Answer:

The troposphere is the layer of air closest to earth, the place where we live. It contains 75% of the air, by mass, and is where air currents and storms occur that mix the air in our atmosphere.

17. Answer:

Symbolic = CO_2

Particulate = 

Macroscopic = 

18. Answer:
NO_2 = nitrogen dioxide
N_2O = dinitrogen monoxide
NO = nitrogen monoxide
NCl = nitrogen trichloride
N_2O_4 = dinitrogen tetraoxide

19. Answer:

CCl_4 = carbon tetrachloride
SO_3 = sulfur trioxide
Cl_2O_6 = dichlorine hexaoxide
P_4S_3 = tetra phosphorus trisulfide

20. Answer:

a. $400\,\text{parts per million} \times \dfrac{100\,\text{parts per hundred}}{1{,}000{,}000\,\text{parts per million}} = 0.04\,\text{parts per humdred} = 4\%$

b. Carbon monoxide is an air pollutant because when breathed into the lungs, CO can be hazardous to human health.

c. Carbon monoxide interferes with the ability of hemoglobin to carry oxygen throughout your body. If you are exposed to CO in high enough concentrations, it can cause a person to die due to lack of oxygen. Shorter term exposure leads to dizziness or a headache.

21. Answer:

a. You will most likely find sulfur dioxide and nitrogen dioxide close to their sources (i.e. coal fired power plants and automobiles), around cities in the troposphere, although they can travel on air currents to other parts of the world.

b. Sulfur dioxide is more toxic. The U.S. Ambient Air Quality Standards sets a limit of 0.075 ppm for a one-hour exposure, as opposed to nitrogen dioxide at 0.100 ppm for a one-hour exposure.

c. $0.045\,\text{parts per million} \times \dfrac{1{,}000{,}000{,}000\,\text{parts per billion}}{1{,}000{,}000\,\text{parts per million}} = 45\,\text{parts per billion}$

22. Answer:

$6\text{ m} \times 5\text{ m} \times 3\text{ m} = 90\text{ m}^3$

$$3600\,\text{mg acetone} \times \frac{1000\,\mu\text{g}}{1\,\text{mg}} \times \frac{1}{90\,\text{m}^3} = 40{,}000\,\frac{\mu\text{g}}{\text{m}^3}$$

Concentrating on Concepts

23. Answer:

The Hydra photograph shows sea walls, presumably built by humans (requiring fuel to be burned in the process of moving the stones). If the stones are cemented, the cement also will emit gases as it dries. The ships are giving off emissions from the burning of fuel. The restaurant might be emitting the good smells of fresh Greek food.

The Tianjin photograph is easier. The cars and buses on the road leave air prints as they burn fuel. Any spilled fuel may evaporate into the air. The haze is most likely the result of emissions from vehicles and industry nearby.

24. Answer:

Carbon monoxide: Mild CO poisoning makes you feel crummy, including headache, dizziness, and nausea. You will not be able to exert yourself in your normal manner. More severe poisoning may send you unconscious to the emergency room.

Particulate matter: Mild PM poisoning will cause lung and cardiovascular distress. Again, you will not feel up to things with your normal energy level. More severe poisoning can send you to the emergency room with a heart attack.

Ozone: Mild ozone poisoning will cause your eyes and throat to burn. It will aggravate your breathing and asthma. As with CO and PM, more severe ozone poisoning can send you to the emergency room.

25. **Answer:**

Answers will vary depending on the answer calculated in Your Turn 2.2 and the size of the classroom. For most students, the volume of air inhaled in a day will be on the order of 10,000 L. The classroom length, width, and height measurements can be estimated in meters. One cubic meter equals 1,000 liters, so classrooms should hold a much greater volume of air than a student exhales in a day.

26. Answer: In respiration, inhaled oxygen reacts with substances in your body to produce carbon dioxide and water vapor. Therefore, exhaled air has a decreased percentage of oxygen, and increased

percentage of carbon dioxide.

27. Answer:

a. Normally, the exhaust gases are released to the atmosphere through the tailpipe and do not find their way back into the interior of the car. The tailpipe does not have a connection to the interior. However, if the gases are released into an enclosed space like a snow bank, they may seep back into the car as there is no easy escape path into the wider environment.

b. CO is an odorless, colorless, and tasteless gas.

28. Answer:

Here are some possibilities:

- Iron and steel would rust more slowly, prolonging the useful life of many objects made from these materials.
- Fires would burn less vigorously and produce more CO and soot. Logs in your fireplace might last longer, putting out heat more slowly.
- Your body can adapt (just as it does at higher elevations) to lower levels of oxygen. But in this case, the level may be too low for metabolic processes involving oxygen to occur at fast enough rates for life as we currently know it.

29. Answer:

CO is termed the "silent killer" because your senses cannot detect this colorless, tasteless, and odorless gas. The same term cannot be applied to pollutants such as O_3 or SO_2 because each has a distinctive odor that can be detected at concentrations below the level of toxicity.

30. Answer:

a. To convert from percent to ppm, move the decimal point 4 places to the right. Alternatively:

$$3\% = 3\,\text{pph}$$

$$3\,\text{pph} \times \frac{1{,}000{,}000\,\text{ppm}}{100\,\text{pph}} = 30{,}000\,\text{ppm}$$

$$3\text{pph} \times \frac{1{,}000{,}000{,}000\text{ppb}}{100\text{pph}} = 30{,}000{,}000\text{ppb}$$

b. The NAAQS for CO in an 8-hour period is 9 ppm. The concentration of CO in cigarette smoke is over three thousand times the 8-hour standard. The NAAS for CO in a 1-hour period is 35 ppm. The concentration in cigarette smoke is almost nine hundred times the 1-hour standard.

c. Smokers do not die from CO poisoning because they breathe mainly air, not pure cigarette smoke.

31. Answer:

The ozone levels are not reported in the winter because of the differences in the sunlight between the

summer and the winter. Even at its greatest winter intensity, the sunlight is much less intense. Sunlight is needed to produce ozone.

32. Answer:

Reporting the absolute difference, 0.01 ppm, seems to minimize the amount by which the standard is exceeded, at least in the eyes of the general public. Unless the standard is reported as well, there is no way to compare the magnitude of the difference to the magnitude of the standard. Calculating the percentage by comparing the difference (0.01 ppm) to the standard (0.12 ppm) gives 8%, which may give people a better understanding of the amount by which the standard was exceeded.

33.**Answer:**

a. The elderly, the young, and people with respiratory diseases such as asthma and emphysema are most affected by ozone.

b. 3 days

c. Ozone is highly reactive, thus does not persist long in the atmosphere. Since no ozone is produced at night when the sun isn't shining, its concentration falls.

d. Answers will vary. Possibilities include: overcast skies, rain, or high winds. It could be a day when fewer people are driving or that industries are shut down.

e. Ozone levels in Atlanta, Georgia, are lower in December because there is less daylight in the winter months.

34. Answer:

a. The elderly, the young, and people with respiratory diseases such as asthma and emphysema are most affected by PM.

b. December 21-22, December 27, December 31

c. Although PM varies in composition, most of it is less chemically reactive than ozone. It typically is removed from the air by rain or wind.

d. Possibilities include smoke blowing in from a wildfire outside the city, an air inversion, large industrial releases of soot, and a volcanic eruption somewhere in the region that released ash and soot.

35. Answer:

a. 15 ppm is 0.0015% and 2% is 20,000 ppm. 15 ppm is roughly 1300 times smaller than 20,000.

b. $2\ SO_2 + O_2 \longrightarrow 2\ SO_3$

c. $2\ C_{12}H_{26}\ (l) + 37\ O_2(g) \longrightarrow 24\ CO_2(g) + 26\ H_2O(g)$

d. Ultimately, burning diesel which is derived from the fossil fuel petroleum is not sustainable. In the short term, diesel engines also are old and have high emissions. So these have a high cost in terms of public health. However, the ultra-low sulfur diesel fuel is definitely a step in the right direction.

36. Answer:

a. These regions have high population densities, high levels of vehicle emissions, possibly stagnant air, and lots of sunlight. Factors such as these lead to ozone formation.

b. Possibilities include that it is overcast and/or raining in the Midwest.

c. In the Sacramento Valley, air may become trapped such that air pollutants accumulate. Furthermore, the temperatures are higher and the days are sunnier, promoting ozone formation. In

contrast, the air near the coastline has better circulation, which promotes better air quality. The air also is cooler and sometimes foggy.

37. Answer:

If you live in the U.S., check http://www.stateoftheair.org/, the *State of the Air*. You can easily count the ozone days in different states. You will find that the sunnier states in the south and southwest have higher levels of ozone beginning earlier in the year than those in the north.

38. Answer:

a. Reducing the number of cars in use will directly and indirectly reduce the concentrations of NO_x, SO_x, CO, CO_2 and ozone in the air.

b. Geographical features that lead to stagnant air, such as being situated in a valley or surrounded by mountains, may contribute to the higher ozone levels.

39. Answer: CO is a hazard when present at the part per million level, and instruments can easily detect CO at this concentration. In contrast, radon levels are much lower, on the order of parts per 10^{20}. Most radon detection kits sample the air over a period of time in order to get a high enough reading.

40. Answer:

a. The label could read "Low VOC paints reduce your exposure to paint fumes, minimizing the exposure and risks associated with these fumes."

b. VOCs are a player in the formation of NO_2 from NO. In turn, NO_2 breaks down in sunlight to produce O atoms that react with O_2 molecules to produce ozone in the troposphere.

41. Answer:

a. Jogging outdoors, as opposed to sitting outdoors, increases your exposure to air pollutants because you will be breathing harder and exchanging more air during your exercise.

b. Jogging indoors reduces your exposure to ozone (the O_3 molecule is highly reactive and decomposes during the time it takes to transport the air inside). In contrast, particulate matter has comparable levels inside and out (PM does not get filtered out by most air-handling equipment and it is not highly reactive). Some pollutants may be found at higher levels inside, such as the CO produced by faulty appliances.

42. Answer:

One possibility is to examine how you (and your clients, if you have them) use energy over the course of a day (heating, lighting, computing time, traveling). Reductions in energy use translate into improved air quality. This is true even for renewable energy sources such as solar and wind, because it still requires energy to manufacture and maintain the solar cells and wind turbines. Another possibility is to seek the connections between your work and air quality. For example, if you are in a medical profession, you could start better educating the public as to the health issues associated with breathing dirty air.

Exploring Extensions

43. Answer:

This phrase refers to what can happen when individuals use a natural resource (e.g., air we breathe, water we drink) that is shared by all for their own interests and then lower the quality of this resource, which is not in the best interest of a larger group of people. Air pollution is a classic example in that people add waste to the air which in turn affects the health and well-being of others. A case in point would be an industry (group of people) that burns coal to produce electricity. In the process of doing this, oxides of nitrogen and sulfide are released into the air. Other waste products include mercury and the greenhouse gas carbon dioxide. Clearly some people benefit, perhaps even those using the electricity. But all breathe the dirty air. Depending on the concentrations of pollutants, some people may sicken or die.

44. A**nswer:**

Fossil fuels contain trace amounts of mercury. When these fuels are burned, the mercury is released into the air. Forest fires and volcanoes are natural sources of mercury air pollution. However, mercury concentrations in the air are usually low and of little direct health concern. When air-borne mercury enters water systems, biological processes transform it to a chemical form (methylmercury, or $(CH_3Hg)^+$) that can accumulate in fish and animals that eat fish. Organisms high in the food chain, such as fish, have the highest levels of mercury. People are exposed to mercury primarily by eating fish. A person's level of mercury exposure can be measured by testing the amount of mercury in their blood. High mercury levels can cause neurological damage and are particularly harmful to fetuses, infants, and young children.

45. Answer:

Visit the EPA website through http://www.epa.gov. The Green Chemistry website can be found at http://www.epa.gov/greenchemistry. The Presidential Green Chemistry Challenge was established by President Bill Clinton in 1995 to promote pollution prevention and industrial ecology in partnership with the chemical industry.

46. Answer:

a. The rubber may have come from tires abrading as they roll along the highways. Other sources of PM include soot from incomplete combustion and dirt picked up and blown by the wind**.**

b. Iron, aluminum, and calcium also are commonly present. Other possibilities include sodium, potassium, magnesium, and sulfur.

c. The edges of the particles appear to be irregular and jagged, thus likely to cause inflammation.

47. Answer:

The American Lung Association website is a good place to start. Particulate matter comes from a variety of sources and can be solids or fine suspensions (aerosols) of liquids. Ultrafine particles can penetrate the lungs more deeply than coarser particles and thus are more likely to enter the bloodstream. Once in blood vessels, these fine particles inflame cells and tissues, leading to cardiovascular disease.

48. Answer:

a. This graph clearly indicates that exposure to higher carbon monoxide concentrations over longer

time periods becomes increasingly life-threatening.
b. CO poses a serious health threat. This gas is colorless and odorless, making it impossible to detect without a monitor or kit. Furthermore, the initial symptoms of carbon monoxide poisoning are not unique, and those suffering from the associated headaches and nausea could easily presume the symptoms are due to a flu-like illness. Untreated, individuals will ultimately lapse into a coma, after which point they will be unable to call for assistance. For these reasons such as these, carbon monoxide detectors are life-saving devices.

49. Answer:
A water-based polyurethane was produced by removing the VOCs from the varnish and replacing them with water. As the source below reports: "This may seem an obvious substitution, but, due to the particular chemistry of the reactive components of polyurethane, it is not that straightforward. The details are given here:
https://www.epa.gov/greenchemistry/presidential-green-chemistry-challenge-2000-greener-reaction-conditions-award
Several paint manufacturers currently market water-based polyurethanes. An internet search will quickly bring up examples.

50. Answer:

The health hazards associated with isocyanate include irritation of the mucous membrane and skin, tightness in the chest, and difficulty breathing. Isocyanate is also a potential carcinogen for humans and is known to cause cancer in animals.

a. Instead of using non-renewable, petroleum based feedstocks to create adhesives, composites, and foams, Professor Wool's processes use feedstocks from bio-based sources. These renewable sources include flax, chicken feathers, and vegetable oils. In addition to being renewable, their production uses less water and energy and is not as toxic as the petroleum based counterparts.