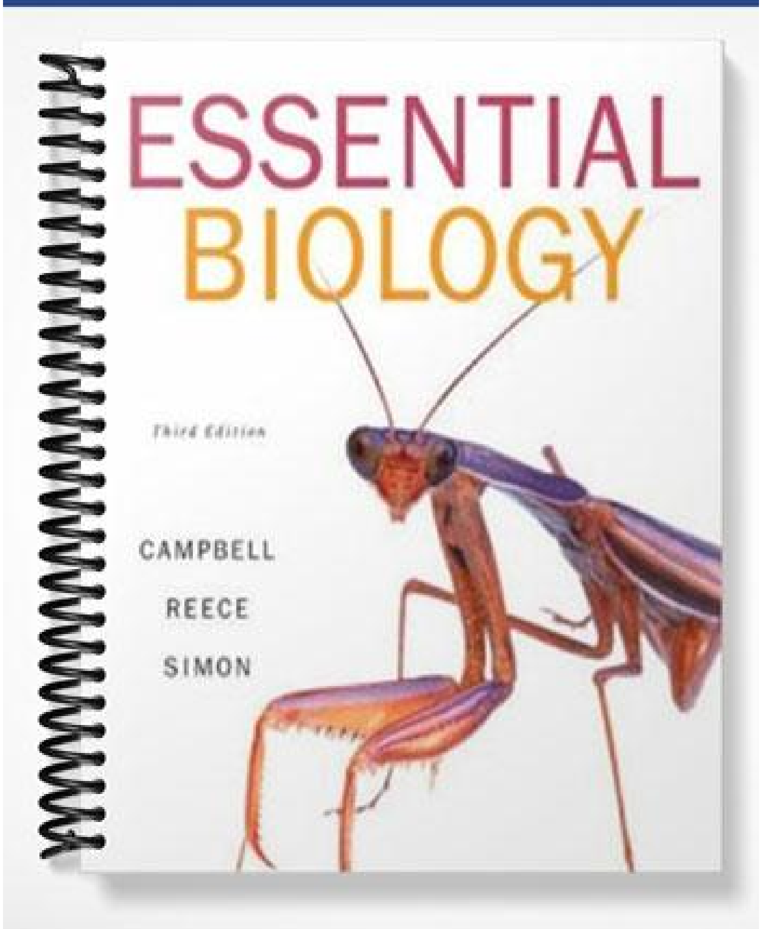
SOLUTIONS MANUAL



CHAPTER 2

Essential Chemistry ▪ for Biology

Why This Chapter Matters

1. Many important biological questions can be reduced to aspects of chemistry.
2. Living organisms are, at their most basic level, chemical systems.
3. Understanding the chemical level of biology requires a basic understanding of chemistry.
4. Water's unique life-supporting properties can be traced to the structure and interactions of its molecules.

Chapter Objectives

Biology and Society: AIDS: A Matter of Chemistry

1. Explain how AIDS can be understood at the cellular and chemical levels.

Some Basic Chemistry

2. Distinguish between matter, chemical elements, and compounds. Give examples of each.
3. Explain the significance of trace elements to human health.
4. Describe the relative size, location, and electrical charge of protons, neutrons, and electrons within an atom. Explain how the atomic number and mass number are determined.
5. Define an isotope and explain how isotopes are used in biological research and medicine.
6. Explain how the location of electrons determines the chemical properties of an atom.
7. Distinguish between ionic, covalent, and hydrogen chemical bonds.
8. Describe the structure of water and explain how its shape makes water a polar molecule.
9. Write the chemical formula for the creation of water from hydrogen and oxygen. Identify the reactants and products of this reaction.

Water and Life

10. Describe the four life-supporting properties of water. Describe an example of how each property affects some form of life.
11. Distinguish between the chemical properties of acids, bases, and neutral solutions. Explain how buffers stabilize the pH of acidic and basic solutions.

Evolution Connection: Earth Before Life

12. Describe the structure of the Earth and its atmospheric conditions that likely existed when life first evolved 3.5–4.0 billion years ago.

Key Terms

acid
aqueous solution
atom

atomic number
base
buffer
chemical bond
chemical reaction
cohesion
compound
covalent bond
electron
element
evaporative cooling
heat
hydrogen bond
ion
ionic bond
isotope
mass
mass number
matter
molecule
neutron
nucleus
pH scale
polar molecule
product
proton
radioactive isotope
reactant
solute
solution
solvent
temperature
trace element

Word Roots

aqua = water (aqueous: a type of solution in which water is the solvent)
co = together; **valent** = strength (covalent bond: an attraction between atoms that share one or more pairs of outer-shell electrons)
iso = equal (isotope: an element having the same number of protons and electrons but a different number of neutrons)
neutr = neither (neutron: a subatomic particle with a neutral electrical charge)

Student Media

Activities

The Structure of Atoms
Electron Arrangement
Build an Atom
Ionic Bonds
Covalent Bonds
The Structure of Water

The Cohesion of Water in Trees
Acids, Bases, and pH

Case Studies in the Process of Science

How Are Space Rocks Analyzed for Signs of Life?
How Does Acid Precipitation Affect Trees?

MP3 Tutors

The Properties of Water

Videos

Discovery Channel Video Clip: Early Life

Relevant Songs to Play in Class

"Doing the Neutron Dance," Pointer Sisters

Chapter Guide to Teaching Resources

Some Basic Chemistry

Student Misconceptions and Concerns

1. Students with limited backgrounds in chemistry and physics might struggle with basic concepts of mass, weight, compounds, elements, and isotopes. It may also be early in the semester when mature study habits have not yet developed. Consider passing along basic studying advice and tips to help students master these early chemistry concepts. In-class quizzes (graded or not) or a few homework problems will also provide reinforcing practice.
2. Students with limited backgrounds in chemistry will benefit from a discussion of Figure 2.5 and the differences and limitations of diagrams of atomic structure. The contrast in Figure 2.5 is a good beginning of such a discussion. In addition to comparing how the positions of electrons are depicted, note the problems with the sense of scale as indicated in the Figure 2.5 legend.

Teaching Tips

1. Students might be interested in the following aside: One of the challenges of raising captive, exotic animals is meeting the unique dietary requirements of the species. A zoo might have trouble keeping a particular animal because science has not fully determined what trace elements the animal requires.
2. Here is a comparison that helps make the point about the differences in mass of protons and electrons. If a proton was as massive as a bowling ball, an electron would be the mass of a Lifesaver. (This is calculated by considering a 15-pound bowling ball, a Lifesaver with a mass of 0.12 ounces, and the textbook's formula that an electron is 1/2,000 the mass of a proton.)
3. Have your students try to calculate the number of covalent bonds possible for a variety of atoms. Then provide the students with a list of elements and the number of outer electrons for each and have them make predictions about the chemical formula for many types of molecules.
4. Consider challenging your students to suggest relationships in human lives that are analogous to each of the three types of chemical bonds discussed. Evaluating the accuracy of potential analogies requires careful analysis of the chemical bonding relationships. Small groups might provide immediate critiques before passing along analogies for the entire class to consider.

Water and Life

Student Misconceptions and Concerns

1. Students are unlikely to have carefully considered the four special properties of water that are apparent in our lives. Yet these properties are of great biological significance and are often familiar parts of our lives. The connections between these properties and personal experiences can invest great meaning into a discussion of water's properties. A homework assignment asking for three examples of each of these properties in each student's experiences will require reflection and potentially produce meaningful illustrations. Similarly, quizzes or exam questions matching examples of each property to a list of the properties requires high-level evaluative analysis.
2. Students at all levels struggle with the distinction between heat and temperature. Students might also expect that all ice is about the same temperature, 0˚C. Redefining and correcting misunderstandings often takes more class time and energy than introducing previously unknown concepts.

Teaching Tips

1. Here is a way to have your students think about the "sticky" nature of water in their lives. Ask them to consider the need for a towel after a shower or a bath. Once we get out of the shower or bath, we have left the source of water. So why do we need the towel? The reason we need a towel to dry off is that water is still clinging to our bodies because water molecules are polar. The molecules on cell surfaces are also polar, so our skin and the water both "stick" to each other.
2. Some students may be intrigued if you tell them that you too can stand on the surface of water—when it is frozen. Thus, it is necessary to note a liquid water surface when talking about surface tension.
3. Have students compare the seasonal ranges of temperatures of Anchorage and Fairbanks, Alaska. (Many websites, such as Yahoo, provide weather information about various cities.) These two northern cities have large differences in their annual temperature ranges. Make the point that the coastal location of Anchorage moderates the temperature.
4. Several versions of the following analogy are easy to relate to students. (a) Ask students how the average on an exam would be affected if the brightest students didn't take the test. (b) The authors note that the performance of a track team would drop if the fastest sprinters didn't compete. In both analogies, removing the top performers lowers the average just like the evaporation of the most active water molecules cools the evaporative surface.
5. "It is not the heat, it is the humidity." The efficiency of evaporative cooling is affected by humidity. As humidity rises, the rate of evaporation decreases, making it more difficult to cool our heat-generating bodies on a warm and humid summer day.
6. Ask your students if the ocean levels would change if ice didn't float. They can try this experiment to find out. Place several large chunks of ice in a glass and fill the glass up completely with water to the top rim. Thus, the ice cubes should be sticking up above the top of the filled glass. Will the glass overflow when the ice melts? (No.) This phenomenon is important when we consider the potential consequences of global warming. If floating glaciers melt, ocean levels will not be affected. But if the ice over land melts, we can expect increased ocean levels.
7. The Environmental Protection Agency (EPA) website (http://www.epa.gov/airmarkets/acidrain/index.html) includes good information about acid precipitation and teaching ideas.

Answers to End of Chapter Questions
The Process of Science
11. Suggested answer: Allow an animal to breathe radioactively labeled oxygen. After the animal has had ample time for aerobic respiration, test the carbon dioxide and water in the exhaled gases to see where the labeled oxygen is found. The primary location of the radioactively labeled oxygen should be in the water molecules formed during aerobic respiration.
12. Suggested answer: These two atoms would form an ionic bond. The potassium atom would donate an electron to the fluorine atom to complete its outer electron shell. The result would be an ionic compound.
Biology and Society
13. Some issues and questions to consider: Is it the kinds of atoms present in chemical wastes that are important, the way the atoms are combined to form particular substances, and/or the concentration of the chemical wastes? How important is the mechanism for chemical waste disposal? Do chemicals produced by human technology differ from naturally occurring substances? If so, how?
14. Some issues and questions to consider: Which is less expensive, power from nuclear power plants or power from fossil-fuel plants? Does the price of electricity reflect its actual cost, including environmental costs? Which would be more harmful: the environmental effects of acid precipitation and global warming from fossil-fuel power plants or the effects of nuclear wastes and potential nuclear accidents?
Additional Critical Thinking Questions
The Process of Science
1. The atomic number for chlorine is 17 and the atomic number for potassium is 19. Draw electron shell diagrams for each atom. Predict what would happen with the electrons if a chlorine atom and a potassium atom came into contact. What kind of bond do you think they would form?
Suggested answer: Chlorine needs 1 electron for a full outer shell of 8, and if potassium loses 1 electron, its outer shell will have 8. Potassium will lose an electron (becoming a 11 ion), and chlorine will pick it up (becoming a 21 ion). The ions will form an ionic bond.
2. A newspaper headline reads “Acid Precipitation Not a Threat.” The article states that the city’s air pollution control board has been monitoring sulfur oxides and nitrogen oxides in the air and recording the pH of precipitation for the past five years. Air samples have been collected daily at two sites: at the busiest downtown intersection and at the entrance to a privately owned electrical power–generating station. On most days, the power station is downwind from the downtown area. Over the period studied, sulfur oxides and nitrogen oxides have increased at both sites, with the power station always having higher levels than the downtown site. However, at no time in the past five years have any of the pollutant levels exceeded the nationally acceptable standards. Moreover, the pH of precipitation has remained essentially the same (slightly acidic) at both monitoring sites throughout the period. City officials have concluded that there is no immediate reason for alarm, that acid precipitation has not been a problem, but that monitoring should continue. The news article, however, goes on to point out that not everyone agrees with the city officials. One resident living 10 miles outside the city is quoted: “The trees on our streets and in our yards are dying from acid precipitation. Five years ago all our trees were healthy, but we’ve lost a dozen in this neighborhood in the past two years. We’re directly downwind from that power plant, and I know acid rain killed my trees. My neighbors and I are going to sue the power company for losses.”

Do you think these residents have the scientific evidence needed to win their lawsuit? Why or why not? Would they have a clear-cut case if a monitoring site had been set up in their neighborhood and data collected there showed an increase in acid precipitation during the five-year period? If the residents hired you as a scientific consultant, what advice would you give them?

Suggested answer: The situation is complex, and the residents' case seems to be weak, at best. Assuming they are downwind from both the city and the power plant, their air might be more polluted and their precipitation more acidic than air sampled at either collection site; however, there seems to be no evidence backing their claim. Evidence from sampling stations suggests that the city and the power plant are adding pollutants to the air, but there is no indication that the added pollution is causing acid precipitation. If samples collected at a monitoring station in the residents' neighborhood showed an increase in acid precipitation, the residents' case might still be weak (they could not tell if the power plant was the main source of pollutants if their air comes from both the city and the power plant). Also, the courts might not view the residents' air pollution problem as serious unless the pollutant levels in their air exceeded national standards. Where would you place sampling stations to get the best idea of the source of air pollutants? Would the residents' case be strengthened if they discovered that the power plant monitoring station was not downwind from the city or that for three of the five years, the wind actually blew in the other direction most days and nights? A scientific consultant might initially suggest a study to determine if other air pollutants, infectious diseases, insects, groundwater pollution, or other factors are responsible for the tree deaths. Would eliminating these factors as causative agents strengthen the acid precipitation case?

Biology and Society

3. Many communities add fluoride to the drinking water supplies because of the ability of fluoride to bond with tooth enamel and prevent cavities, which are holes in the enamel caused by bacteria in the mouth. Fluoride is a negatively charged ion formed when a salt (such as sodium fluoride) is added to water. A tin salt, stannous fluoride, is a common ingredient in toothpaste. Is your water supply fluoridated? If you were choosing whether or not to drink fluoridated water, what questions or concerns would you have before making your decision?

Some issues and questions to consider: What is the evidence that adding fluoride to the water supply is safe? Is there data suggesting that fluoride can have damaging effects on the body? If you discover some of these effects, keep in mind the importance of the concentration of the fluoride tested. How high is the fluoride concentration in fluoride-supplemented water? Since fluoride salts are a significant part of the Earth's crust, small amounts of fluoride are found in all groundwater. What is the range of normal concentrations found throughout the country? How does this concentration compare to the amount added artificially? How strong is the evidence that fluoride reduces the rate of cavities in treated populations? Since fluoride's effect is on the teeth, could applying fluoride directly to the teeth rather than ingesting it in the water be safer?

4. Considering the number of cases of food-borne illness each year, some people (including the U.S. Food and Drug Administration, FDA) have suggested that the irradiation of food is a solution to decreasing illness and death from contaminated foods. In addition, this process helps to extend shelf life and prevent spoilage of perishable foods. During the process, foods are exposed to various types of radiation. This radiation damages and kills any cells that might be living on the surface (such as bacteria). Some people are against the use of irradiation without ever really understanding how the process works. Would you be willing to eat foods that have been irradiated? Should these foods have to be labeled as irradiated? Would you be willing to pay more for these products?

Some issues and questions to consider: Consider the lengthy history of testing irradiation on foods and the current use of radiation on spices. Do irradiated foods become radioactive? Is there any health risk associated with eating these products? Is the expense warranted? How much more will irradiated foods cost? Should the food be labeled to give consumers a choice?