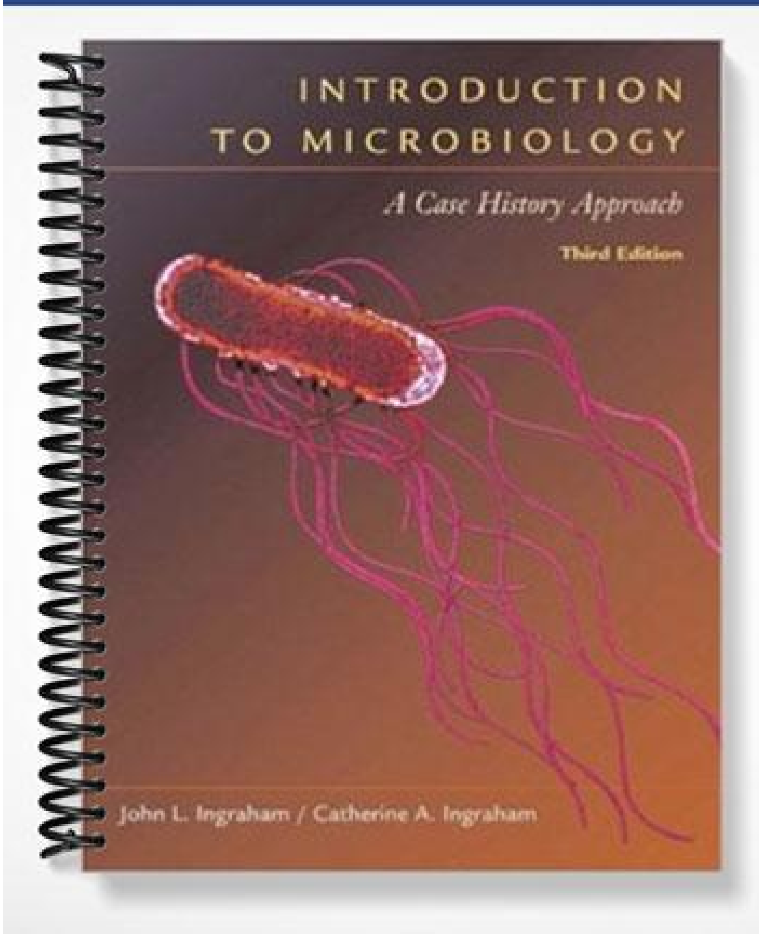
SOLUTIONS MANUAL



Chapter 2
Basic Chemistry

Learning Goals

To understand:

The basic building blocks of matter-subatomic particles, atoms, elements, and molecules

The ways in which atoms bond to make molecules and compounds

What a chemical reaction is, what determines whether a reaction occurs, and what determines the rate of a chemical reaction

The unique chemical properties of water

The structure of organic molecules

The structure of the macromolecules-proteins, nucleic acids, carbohydrates, and lipids—from which all cellular microorganisms are built

Chapter Outline

- The Basic Building Blocks
  - Atoms
  - Elements
  - Molecules
- Chemical Bonds and Reactions
  - Covalent Bonds
  - Ionic Bonds
  - Hydrogen Bonds
  - Chemical Reactions
- Water
  - Special Properties of Water
  - Water as a Solvent
- Organic Molecules
  - Carbon Atoms
  - Functional Groups
- Macromolecules
  - Proteins
  - Nucleic Acids
  - Polysaccharides
  - Lipids
- Summary

Teaching Tips

1. Use the periodic table as you teach the atomic numbers and atomic weights for the biologically important elements. As you display the table, explain the arrangement of the elements in vertical families and horizontal rows.

2. Use three-dimensional, stickball models to illustrate the bonding patterns of atoms in biologically important molecules. Ask your students to take the models apart and put the atoms back together. This will improve their understanding of bonding patterns in molecules.

3. Worksheets, circulated in class and completed by students, offer students a chance to apply concepts learned in any course. The reinforcement provided by these exercises facilitates mastery of the information students need to know. Use this worksheet approach for the class you are teaching. Write some practice problems on the calculation of molecular weights and pH values. Copy these problems and distribute them in class for practice. Can your students calculate the molecular weight of glucose? What is the pH of a solution with a hydrogen ion concentration of 0.000001 grams per liter?

4. Continue the worksheet-practice approach with this idea: Display a list of numbers such as the following: 1, 2, 3, 4, 5, 6, 12, 24, 45, etc. Let each number represent an answer to a possible question that can be written from Chapter 2. For example, questions for the number 6 can be: What is the approximate pH of milk? How many electrons are in the outer energy shell of oxygen? How many carbon atoms are in a molecule of glucose? Theses exercises challenge students to think about the course content in a different way. In addition, these exercises emphasize the quantitative-based concepts stated throughout the chapter.

5. Show your students that chemistry has wide applicability to upcoming topics in microbiology. How does a bacterium ferment glucose? Where is peptidoglycan found in the bacterial cell? What is the genetic significance of the structure of DNA?

6. A study of chemistry has an obvious link to nutrition. Use information about the carbohydrates, lipids, and proteins to show this. Study the labels of some well-known food products. What is their percentages for the different kinds of organic molecules. In addition to the tie-in to human nutrition, show the relevance of these macromolecules to bacterial nutrition. Let students study the makeup of nutrient agar and other kinds of media they will use to culture microorganisms in the lab.

Discussion Topics

1. Life consists of complex molecules. However, these molecules consist of the simplest elements. How did life evolve from this pattern?

2. How are the principles of this chapter important to the topics of bacterial genetics, metabolism, and nutrition?

3. Chemistry courses are prerequisites for courses in microbiology. Specifically, how does background information from these chemistry courses help students understand the concepts in this and other chapters. How does the chemistry -related topics in this course build on students' background and extend their knowledge?

4. The facts and concepts of chemistry have wide applications to other branches of science. Consider the topic of pH. How do buffers in the human body stabilize the pH of the blood or stomach? How do buffers in the bottom of a limestone stream stabilize the pH of this waterway, maintaining a pH that is optimal to support the various kinds of organisms living there? How does a highly-acidic rainfall threaten the ability of buffers to work in this stream?

Correlation Questions

1. The atomic weight of carbon in the periodic table is listed as 12.001. Why is this value not 12.000?

2. How does the computation of a pOH depend on the changing concentration of a free ion in solution?

3. Explain how one isotope of hydrogen has the same atomic number and atomic mass.

4. Potassium has an atomic number of 19. Will it tend to form cations or anions in solution?

Answers: Review Questions

The Basic Building Blocks

1. An atom consists of a nucleus composed of densely packed protons and neutrons. A cloud of electrons surrounds the nucleus. Either a proton or neutron has a mass of one atomic weight unit. The proton is positive and the neutron is neutral. An electron is negative. Its mass is negligible.

2. The valence electrons are located in the outermost shell of the atom. They determine the reactivity and bonding capability of an atom.

3. The atomic number is either the number of protons or number of electrons in an atom. The atomic weight is the number of protons plus the number of neutrons in an atom.

4. Elements are the simplest chemical substances.

5. A molecule is a particle of matter consisting of two or more atoms chemically bonded. A macromolecule is a very large molecule. A compound is a substance composed of molecules with more than one kind of atom. Organic compounds are carbon-containing compounds. They also contain hydrogen. Therefore, carbon dioxide is not an organic compound.

6. The molecular formula of water is two hydrogen atoms followed by one oxygen atom. By knowing the number of atoms of each kind in a molecule, and the atomic weight of each atom, you can compute the molecular weight of a substance. For example, water is 2 (2 x 1 for hydrogen) plus 16 (1 x 16 for oxygen) for a molecular weight of 18.

7. Avogadro's number is 6.02 times 10 raised to the 23rd power. One mole of substance with covalent bonding has this number of molecules. One mole of an ionic substance, such as NaCl, has this number of particles before dissociation.

Chemical Bonds and Reactions

8. Chemical bonds are the forces that hold atoms together in molecules. Chemical bonds form if the molecule produced has a lower energy state than the atoms originally reacting to form it. The valence electrons determine an atom's ability to form chemical bonds.

9. A covalent bond holds atoms together by the sharing of valence electrons. When these electrons are shared equally, and therefore equally spaced in a molecule, a nonpolar covalent bond is produced. With a polar covalent bond, the valence electrons are not shared equally and are not equally spaced in the molecule. Therefore, the molecule has a positive and negative end. Water is the most important polar molecule of life.

10. Ions are atoms that have acquired a complete valence shell by gaining or losing electrons. A cation is a positive ion. An anion is a negative ion.

11. The functions of ions in organisms include signaling environmental changes, serving as intermediates in the cycle of elements in the environment, neutralizing the charges of molecules, and balancing solute concentrations.

12. An ionic bond is a force holding ions or molecules together by the opposite charges of these particles. In NaCl, sodium ions are attracted to chloride ions by ionic bonds.

13. A hydrogen bond forms when a hydrogen atom interacts between two different molecules or between different parts of the same molecule. They stabilize the structure of many large, biologically important molecules such as DNA.

14. Covalent bonds are most stable. Hydrogen ions are least stable.

15. In a chemical reaction atoms or molecules, the reactants, collide and are transformed into new combinations of atoms or molecules, the products.

16. When chemical bonds are broken, energy is released; when chemical bonds are formed, energy is stored.

17. The concentration of reactants, the reaction temperature, and the presence of enzymes are all factors affecting the rate of chemical reactions.

18. Enzymes are important because they speed up chemical reactions to a rate where they support life.

19. A ribozyme is an RNA molecule with enzymatic properties. Whereas a large part of an enzyme molecule is usually a protein, in a ribozyme it is a nucleic acid.

Water

20. Because it forms hydrogen bonds between molecules, water has a high specific heat and heat of vaporization. It is cohesive and can therefore be drawn through distances. As a solid, water has a more open structure, making ice less dense than liquid water. Therefore, ice floats. This affects the melting pattern of lakes. In addition, water is a solvent for many substances.

21. By its polarity, water can attract positive and negative particles of a solute, promoting their dissociation. Water serves as a solvent.

22. Hydrophobic groups are repelled by water. They separate from water, forming important biological barriers. Hydrophilic groups are attracted to water. They dissolve in water.

23. A colloid is a tiny solid particle that draws ions, which in turn attract water molecules. This result forms colloidal dispersions, which are cloudy. Gels are concentrated colloidal dispersions.

24. Hydrogen or hydroxide ions participate in every chemical reaction of living things. The concentration of these free ions in solution determine the pH of a solution. The pH of a solution controls the chemical properties and reactions of the solution.

25. An acid is a compound that dissociates into hydrogen ions in water. A base is a compound that dissociates into hydroxide ions or removes hydrogen ions in water. A salt is an ionic compound consisting of a positive ion, such as sodium, and a negative ion, such as chloride.

26. The pH scale is a numerical scale showing how acidic or basic a solution is. It is logarithmic because a change of one number on this scale represents a tenfold change in the hydrogen ion concentration of a solution. For example, a pH of 3 is ten times more acidic than a pH of 4.

27. Buffers are compounds that stabilize the pH of a solution. In living systems they resist changes in pH, holding the level of acidity to an optimal level. They are used in labs to stabilize the pH of reaction mixtures.

Organic Molecules

28. Biochemistry is the study of carbon-containing molecules of organisms.

29. A carbon atom has great bonding versatility, as it can form four covalent bonds. These bonds can be with other elements or other carbon atoms. This leads to a large variety of carbon compounds.

30. Functional groups are atoms other than carbon or hydrogen that bond to organic molecules. Examples include the carboxyl and amino groups.

Macromolecules

31. A polymer is a macromolecule consisting of repeating, bonded subunits called monomers. The monomers unite by the process of polymerization.

32. Macromolecules are formed by the bonding of subunits through dehydration synthesis. Each time a covalent bond is formed, a water molecule is lost. Hydrolysis is the reverse of this process. A water molecule added to the bond breaks the bond, making the subunits available in a cell.

33. Amino acids, through peptide bonds, form proteins. Functions of proteins include structural building, transport, movement, and enzymatic roles.

34. L-isomers and D-isomers are mirror-image structural forms of amino acids. Only the L-isomers are found in proteins in nature. D-isomers are found in the peptidoglycan molecules of bacterial cell walls.

35. The primary structure of a protein is the specific sequence of bonded amino acids. The secondary structure is the shape of the molecule, such as an alpha helix, from hydrogen bonding. The tertiary structure involves further folding by the interaction of R groups. In the quaternary structure, different protein chains fit together. Denaturation is the disrupting of the secondary, tertiary, and quaternary structures through intense heat and other physical changes.

36. DNA is the nucleic acid encoding genetic information. RNA is the nucleic acid that builds proteins in a cell.

37. Nucleotides are the building blocks of nucleic acids. They are joined by phosphodiester bonds.

38. DNA and RNA are both nucleic acids consisting of bonded nucleotides. DNA is double-stranded. RNA is usually single-stranded. The sugar in the nucleotide of DNA is deoxyribose; it is ribose in RNA. The different nucleotides of DNA and RNA share three common bases: adenine, cytosine, and guanine. In DNA the fourth base is thymine. In RNA it is uracil.

39. ATP is the universal energy currency in the cell. cAMP is a messenger molecule in the cell. NAD and FAD are hydrogen carriers.

40. The carbohydrates are a class of organic compounds. Monosaccharides are the building blocks. Polysaccharides are macromolecules consisting of bonded monosaccharides. Important monosaccharides include glucose and fructose, which serve as a direct source of energy for cells.

41. Glycoside bonds link monosaccharides in a polysaccharide. Cellulose is a structural component in the cell wall of plants and bacteria. Starch is a molecule storing energy in plants and bacteria. Glycogen stores energy in animals. Polysaccharides are important for structure and energy storage in bacteria.

42. Lipids are defined as any nonpolar molecule. Three fatty acids bond to glycerol by ester linkages in triglycerides.

43. One of the three fatty acids bonded to glycerol is replaced by a phosphate group in a phospholipid.

44. Peptidoglycan is a macromolecule. Its configuration resembles an endless sheet forming a hollow structure. It has protein and polysaccharide components and confers strength to the cell wall of the bacterial cell.

Answers: Correlation Questions in the Textbook

1. Each element consists of one, unique kind of atom. Therefore, the number of different kinds of elements or atoms is the same. However, considering isotopes of an element, this makes the number of kinds of atoms greater than the number of elements. For example, the element hydrogen has three different isotopes. Oxygen has two isotopes.

2. Hydrogen is the smallest, simplest atom. This makes it easier to bond with other atoms that have unbonded electron pairs.

3. At a pH of 7 the hydroxide ion concentration is ten to the negative seven or 0.0000001 grams per liter. At a pH of 10, the hydroxide ion concentration is ten to the negative four or 0.0001 grams per liter. The difference between these two concentrations is three decimal places or a one thousandfold difference.

4. The atomic number for an element is its number of protons. The atomic weight of that element is the number of protons plus the number of neutrons. One isotope of hydrogen has one proton and lacks neutrons. In this isotope the atomic number and atomic weight each have a value of one. In other isotopes of hydrogen, and in other elements, adding the number of neutrons to the number of protons makes the atomic weight a higher number than the atomic number.

5. Sketch the structural formula for formic acid.

6. The electron arrangement of magnesium is 2 - 8 - 2. It can lose two outer-shell electrons and become plus two as an ion.

Answers: Essay Questions

1. Hydrogen bonds add stability to the structure of many different macromolecules. Without this bonding these molecules would not have the stability to carry out their biological functions.

2. Catalysts speed up the rate of chemical reactions. Without this increased speed these reactions could not support life processes.

Answers: Discussion Topics

1. Start with the idea that simple atoms can be assembled into more complex subunits. It is the arrangement and repeating pattern of these subunits that led to the formation of the complex macromolecules of life.

2. Examples to use are protein synthesis, starch hydrolysis, and the fermentation of various sugars. Although these topics will be studied in more depth, students will have enough background from this chapter to start understanding the bridge between chemistry and nutrition.

3. Students should have learned about the basic bonding properties of atoms before entering a course in microbiology. However, in microbiology they will be applying fundamental principles in new contexts. For example, students will now study simple atoms they have learned about previously—they will learn about them now in a peptidoglycan molecule. Nitrogen forms three covalent bonds in a molecule of ammonia or in a complex protein molecule.

4. In any buffer system, a buffer releases or takes up free hydrogen ions. By controlling the concentration of free hydrogen ions in solution, they control the pH value of that solution. In the case of acid rain in a stream, a point can be reached when there is insufficient buffer to bind and release hydrogen ions. Uncontrolled at this point, the pH can change. For example, an increase of free hydrogen ions (unbuffered) can make the stream more acidic.

Correlation Questions in the Instructor's Manual

1. The value of 12.001 is a weighted average of all carbon atoms in a sample. Although most of the atoms have an atomic weight of 12, a few have atomic weights of 13 or 14.

2. The pOH is depends on the concentration of hydroxide ions in solution. For example, if the concentration of this ion is 0.00000001, its concentation is 10 to the negative 8 power. This exponent, minus eight, converts to a pOH of 8.

3. The most common isotope of hydrogen has one proton and one electron. It lacks a neutron. Therefore, the atomic number (number of protons) and atomic weight (number of protons plus the number of neutrons) have the same value in this isotope.

4. The electron arrangement in potassium, from the inside energy level to the outermost energy level, is 2 - 8 - 8 -1. With one electron in its outermost energy shell, potassium tends to lose this one negative charge and form a positive ion, a cation.