

PART I THE CELL

2

BASIC CHEMISTRY

CHAPTER REVIEW

Life has a chemical basis. All **matter**, living or nonliving, consists of **elements** composed of discrete units called **atoms**. The atom of each kind of element has its own arrangement of three subatomic particles: protons, neutrons, and electrons. The **protons** (positively charged) and **neutrons** (neutral) are located in the nucleus of the atom. The atoms of an element can differ by their number of neutrons. The **electrons** (negatively charged) are located in energy levels at varying distances from the nucleus. In a neutral atom, the number of protons equals the number of electrons; this is the atomic number of the atom (element). Atoms with the same atomic number but a different number of neutrons are called **isotopes**.

The arrangement and behavior of electrons—specifically the outermost electrons—determine the chemical properties of that element. The electrons are located in **electron shells** around the nucleus. The first shell is closest to the nucleus, the second shell is the next closest, and so forth. The potential energy of an electron increases with the increasing distance of these energy levels from the nucleus. **Orbitals** are the volumes of space where electrons are found within these electron shells. The first shell holds a maximum of two electrons, the second shell holds a maximum of eight electrons, and the third shell holds eight electrons when it is the outer shell. This description applies to atoms of an atomic number less than 20.

The number of electrons in the outer shell determines the chemical reactivity of an atom. Atoms with two or more shells are most stable when the outer shell has eight electrons. For atoms with only one shell (i.e., H, atomic number of 1), the stable electron configuration is two. Atoms fulfill their stable, outer-shell electron configuration by either sharing or transferring electrons with other atoms; that is, they form bonds. Two major types of bonds

can form: ionic and covalent. **Ionic bonds** form by the transfer of electrons between an electron donor and an electron acceptor. Following an ionic reaction, the donor atoms are positively charged **ions**, and the acceptor atoms are negatively charged ions. An ionic bond is the attraction between oppositely charged ions.

By contrast, **covalent bonds** develop from the sharing of electrons between atoms. A covalent bond is often represented by overlapping circular representations of the outer shells or by drawing a straight line between the atoms. The three-dimensional shape of a covalent molecule often determines the role it plays in cells and organisms.

Water is an important biological **compound**, making life possible on earth. Water **molecules** exhibit **polar covalent bonding**. The electrons between atoms (H and O) are shared, but not equally. The shared electrons spend more time near the oxygen atom. This establishes a positive pole (hydrogen atoms) and a negative pole (oxygen atoms) and promotes **hydrogen bonding** between the water molecules. This weak bond between the molecules is the source of many remarkable properties of water, such as its role as a universal solvent, its ability to resist temperature changes and remain a liquid, and its formation of a maximum density at 4°C.

Acids (e.g., HCl) are compounds that release hydrogen ions in solution; **bases** (e.g., NaOH) are compounds that take up hydrogen ions or release hydroxide ions in solution. The **pH scale** indicates the relative concentration of hydrogen and hydroxide ions in a solution. The scale ranges from 0 to 14, with 7 a neutral pH. Acids lower the pH of a solution from 7 by releasing hydrogen ions, and bases increase the pH above 7 by an opposite effect. **Buffers** are compounds in solution that resist these changes through chemical reaction, thus stabilizing the pH of a given solution.

STUDY EXERCISES

Study the text section by section as you answer the questions that follow.

2.1 CHEMICAL ELEMENTS (PP. 20–23)

- Matter is composed of 92 naturally occurring elements, each having one type of atom.
- Atoms have subatomic particles: electrons, protons, and neutrons.
- Atoms of the same type that differ by the number of neutrons are called isotopes.
- Atoms are characterized by the number of protons and neutrons in a nucleus and the number of electrons in shells about the nucleus.

1. Name the six elements commonly found in living things. _____
2. The three most stable subatomic particles in an atom are _____, _____, and _____.
3. An atom has nine protons and nine neutrons in each of its atoms. Its atomic number is ^a_____, its atomic mass is ^b_____, and the number of electrons in this atom is ^c_____.
4. In the periodic table of chemical elements, the horizontal rows are called ^a_____ and the vertical columns are called ^b_____. The atoms in group 8 are called the ^c_____ because they ^d_____ react with other atoms.
5. Isotopes have the same atomic ^a_____, but they differ in the number of ^b_____.
6. At least two forms of the oxygen atom exist in the environment: $^{16}_8\text{O}$ and $^{18}_8\text{O}$.
 - a. Each atom has eight electrons. $^{16}_8\text{O}$ and $^{18}_8\text{O}$ represent _____ of the element oxygen.
 - b. The numbers 16 and 18 represent the _____.
 - c. The atomic number of $^{16}_8\text{O}$ is _____.
 - d. The atomic number of $^{18}_8\text{O}$ is _____.
 - e. The number of protons in the atom of $^{16}_8\text{O}$ is _____.
 - f. The number of neutrons in the atom of $^{18}_8\text{O}$ is _____.
 - g. How do $^{16}_8\text{O}$ and $^{18}_8\text{O}$ differ in number of subatomic particles? _____.
7. Complete the following table with the correct numbers:

Isotope	Protons	Neutrons	Atomic Number	Atomic Mass
$^{12}_6\text{C}$				
$^{14}_6\text{C}$				
$^{31}_{15}\text{P}$				
$^{33}_{15}\text{P}$				

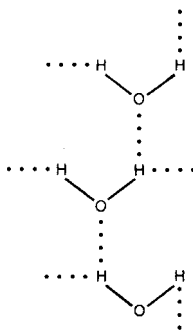
8. Indicate whether these statements are true (T) or false (F):
- _____ A neutral atom has the same number of protons and electrons.
 - _____ The arrangement of protons and neutrons in an atom determines the atom's chemical properties.
 - _____ The electrons of an atom are located in energy levels (electron shells) at varying distances from the nucleus.
 - _____ Electrons in the first shell possess more energy than do electrons in the second shell.
 - _____ When a chlorophyll molecule absorbs solar energy, electrons move to higher energy levels.
9. Electrons are most often found in volumes of space called ^{a.}_____. The orbital at the first energy level is ^{b.}_____ shaped. Of the four orbitals at the second energy level, one is ^{c.}_____ shaped and three are ^{d.}_____ shaped.
10. An atom of an element with an atomic number of 9 has ^{a.}_____ electrons in its first shell and ^{b.}_____ electrons in its second shell.
11. An atom of the element neon (Ne) has eight electrons in its outer shell. An atom of the element sulfur (S) has six electrons in its outer shell.
- Which atom is reactive? _____
 - Which atom is inert? _____
 - Why is there a difference in the reactivity of these two elements? _____
-
12. The magnesium atom has an atomic number of 12 and an atomic weight of 24. Draw its simplified atomic structure. Draw small circles to indicate the general distribution of electrons in concentric levels around the nucleus. In the nucleus, indicate the number of protons and neutrons.

2.2 ELEMENTS AND COMPOUNDS (PR. 24–26)

- Atoms react with one another by giving up, gaining, or sharing electrons.
- Bonding between atoms results in molecules with distinctive chemical properties and shapes.
- The biological role of a molecule is determined in part by its shape.

13. Which of the following are examples of compounds? _____
- ¹⁴C
 - H atom
 - O₂, oxygen molecule
 - NaCl, table salt
 - H₂O, water molecule

14. Calcium (Ca) has an atomic number of 20; chlorine (Cl) has an atomic number of 17.
- The number of electrons in the outer shell of calcium is _____.
 - The number of electrons in the outer shell of chlorine is _____.
 - In a chemical reaction between these two atoms, _____ calcium atom(s) will react with _____ chlorine atom(s).
 - Which element will gain electrons in this reaction? _____
 - What will its charge be after the reaction? _____
 - Which element will lose electrons in this reaction? _____
 - What will its charge be after the reaction? _____
 - What type of bond forms between these two atoms? _____
 - Write the formula for the compound produced through this chemical reaction. _____
15. Water is a polar molecule.
- Indicate on the following diagram which atoms are electronegative (i.e., δ^-) and which are electropositive (i.e., δ^+) in relation to the others. Put a δ^- charge and δ^+ charges where appropriate.
 - Label a hydrogen bond.



16. Place the appropriate letter next to each statement.
- C—covalent bonding I—ionic bonding H—hydrogen bonding
- ____ Electrons transfer between atoms.
 - ____ Atoms share electrons.
 - ____ This bond is present in sodium chloride.
 - ____ This bond is present in the oxygen molecule.
 - ____ A triple bond of this type is present in nitrogen gas.
 - ____ This bond forms between water molecules.
 - ____ The hydrogen atom in one molecule is attracted to the oxygen atom of another molecule.
 - ____ This bond forms within a water molecule.

2.3 CHEMISTRY OF WATER (PR. 27–30)

- The existence of living things is dependent on the chemical and physical characteristics of water.
- Living things are sensitive to the hydrogen ion concentration $[H^+]$ of solutions, which can be indicated by using the pH scale.

17. In each of the pairs of statements that follow, place a check next to the one that correctly describes how hydrogen bonding affects the properties of water. Hydrogen bonding causes water

Pair 1

- a. to boil at a lower temperature than expected.
- b. to boil at a higher temperature than expected.

Pair 2

- c. to be more dense as ice than as liquid water.
- d. to be less dense as ice than as liquid water.

Pair 3

- e. to absorb heat with a minimal change in temperature.
- f. to absorb heat with a maximum change in temperature.

Pair 4

- g. to be cohesive—the water molecules cling to each other.
- h. molecules to shun one another.

18. Refer to the chemical properties of water when answering the following questions:

- a. What makes water a good solvent? _____
- b. How does water moderate temperatures? _____
- c. What allows ice to float on liquid water? _____

19. Place the appropriate letter next to each statement.

A—acid B—base

- a. They take up hydrogen ions in solution.
- b. HCl is an example.
- c. NaOH is an example.
- d. They release hydrogen ions in solution.
- e. They lower the pH.
- f. They raise the pH.

20. Complete the table for the following hydrogen ion concentrations $[H^+]$:

$[H^+]$	pH	Acid/Base/Neutral
1×10^{-7}		
1×10^{-3}		
1×10^{-8}		

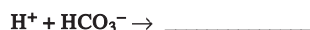
21. Indicate whether these statements are true (T) or false (F):
- ____ If the pH of blood changes from 7.4 to 7.6, it becomes more acidic.
 - ____ When an acid is added to a solution, the pH decreases.
 - ____ A basic pH indicates that OH^- ions outnumber H^+ ions.
 - ____ An acidic pH indicates that H^+ ions outnumber OH^- ions.

22. The following questions relate to buffers:

How do living things prevent drastic changes in pH?

a. _____

b. Complete the following reaction, showing how the carbonic acid buffer system deals with increasing hydrogen ions in the blood:



c. Complete the following reaction, showing how the carbonic acid buffer system deals with decreasing hydrogen ions in the blood:



CHAPTER TEST

OBJECTIVE QUESTIONS

Do not refer to the text when taking this test.

- | | |
|---|--|
| <p>____ 1. An element has an atomic number of 11 and an atomic weight of 23. The number of neutrons in each atom is</p> <ol style="list-style-type: none"> 11. 12. 23. 24. <p>____ 2. The atom of an element has one proton and two neutrons. Its atomic number is</p> <ol style="list-style-type: none"> 1. 2. 3. 6. <p>____ 3. The atom of an element has six protons and eight neutrons. The number of electrons in this atom if neutral is</p> <ol style="list-style-type: none"> 6. 8. 12. 14. <p>____ 4. The relationship between $^{12}_6\text{C}$ and $^{14}_6\text{C}$ is that they are</p> <ol style="list-style-type: none"> molecules. isomers. isotopes. polymers. | <p>____ 5. An atom has 11 electrons and 12 neutrons. Its atomic mass is</p> <ol style="list-style-type: none"> 1. 11. 12. 23. <p>____ 6. The energy possessed by electrons in the first shell is _____ than the energy possessed by electrons in the second shell.</p> <ol style="list-style-type: none"> greater less <p>____ 7. An element has an atomic number of 14. Its electron distribution over several energy shells is</p> <ol style="list-style-type: none"> 1-4-8. 1-8-5. 2-8-2. 2-8-4. <p>____ 8. An element has an atomic number of 13. The number of electrons in each atom's second shell is</p> <ol style="list-style-type: none"> 1. 2. 4. 8. <p>____ 9. Select the reactive element by its atomic number.</p> <ol style="list-style-type: none"> 2 10 12 18 |
|---|--|

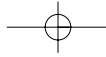
- ___ 10. Select the most stable element by its atomic number.
- 1
 - 8
 - 10
 - 16
- ___ 11. Select the compound.
- Ca
 - H
 - NaCl
 - O₂
- ___ 12. The atoms of which element tend to lose electrons in a chemical reaction?
- Cl
 - Mg
 - O
 - S
- ___ 13. When sodium interacts with chlorine, sodium loses an electron while chlorine gains one. This interaction forms
- an ionic bond.
 - a condensation synthesis.
 - a condensation.
 - a covalent bond.
- ___ 14. Select the incorrect association.
- covalent bond—electrons transferred
 - hydrogen bond—between water molecules
 - ionic bond—charged particles formed
 - polar covalent bond—present in the water molecule
- ___ 15. Bonds between carbon and hydrogen or oxygen and hydrogen are generally
- hydrogen bonds.
 - ionic bonds.
 - covalent bonds.
 - weak and highly transient.
- ___ 16. Each is a property of water EXCEPT
- easily changed from liquid to gas.
 - good solvent.
 - maximum density at 4°C.
 - molecules are cohesive.
- ___ 17. Select the correct statement about acids.
- They cannot be buffered in a solution.
 - They donate hydroxide ions in solution.
 - HCl is an example.
 - They tend to raise the pH.
- ___ 18. Select the most basic pH of the given hydrogen ion concentrations.
- 1×10^{-3}
 - 1×10^{-4}
 - 1×10^{-9}
 - 1×10^{-12}
- ___ 19. Select the incorrect statement about bases.
- They can be buffered in solution.
 - They release hydroxide ions in solution.
 - NaOH is an example.
 - They tend to lower the pH.
- ___ 20. Which of the following is an example of a buffer?
- carbonic acid
 - hydrogen ion
 - hydroxide ion
 - NaCl

CRITICAL THINKING QUESTIONS

Answer in complete sentences.

21. Element X has an atomic number of 4, whereas element Y has an atomic number of 18. Which element is more reactive, and why?
22. Chemical reactions in the human body produce many acid end products. Yet, the pH of the blood remains remarkably constant. Why?

Test Results: _____ number correct ÷ 22 = _____ × 100 = _____ %



EXPLORING THE INTERNET

The Online Learning Center at www.mhhe.com/maderbiology8 has additional study material and practice quizzes that can help you master the content of this chapter. You can also find links to websites exploring additional topics in biology. Access to the Online Learning Center is free for those who have purchased a new textbook.

ANSWER KEY

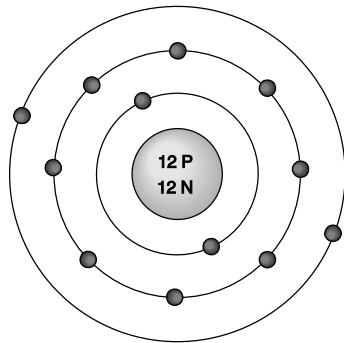
STUDY EXERCISES

1. carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur
 2. protons, neutrons, electrons
 3. a. 9 b. 18 c. 9
 4. a. periods b. groups c. noble gases d. rarely
 5. a. number b. neutrons
 6. a. isotopes b. atomic mass c. 8 d. 8 e. 8 f. 10 g. $^{16}_8\text{O}$ has eight neutrons in its nucleus; $^{18}_8\text{O}$ has ten neutrons.
 7.

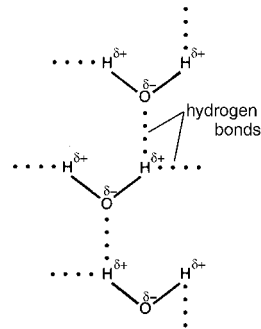
8. a. T b. F c. T d. F e. T
 9. a. orbitals b. spherical c. spherical d. dumbbell
 10. a. two b. seven
 11. a. S b. Ne c. S has six electrons in its outer shell, and if it reacts to gain two more it will have a stable outer configuration of eight; Ne already has a stable outer shell.

Protons	Neutrons	Atomic Number	Atomic Mass
6	6	6	12
6	8	6	14
15	16	15	31
15	18	15	33

12.



13. d, e
 14. a. two b. seven c. one, two d. Cl e. -1 f. Ca g. +2 h. ionic i. CaCl_2
 15.



16. a. I b. C c. I d. C e. C f. H g. H h. C 17. b, d, e, g 18. a. The partial charges of the water molecule attract and disperse charged particles in solution. b. It takes up and releases large amounts of heat without much change in temperature. c. Water is most dense at 4°C. It expands as the temperature drops from this point; it is less dense at 0°C, the temperature of ice. 19. a. B b. A c. B d. A e. A f. B 20.

pH	Acid/Base/Neutral
7	neutral
3	acid
8	base

21. a. F b. T c. T d. T 22. a. The pH is stabilized through the action of buffers, chemical systems that absorb either H⁺ or OH⁻ to keep the pH steady. b. H₂CO₃ c. HCO₃⁻ + H⁺

CHAPTER TEST

1. b 2. a 3. a 4. c 5. d 6. b 7. d 8. d 9. c 10. c 11. c 12. b 13. a 14. a 15. c 16. a 17. c 18. d 19. d 20. a 21. Element X is more reactive because its electron arrangement is 2-2. It has only two electrons in its outer shell. If it gives up these two electrons, its outer shell will be stable. The electron arrangement in Y is 2-8-8. It has eight electrons in its outer shell—a stable outer shell. 22. Buffers in the body take up excess hydrogen ions and thereby act to keep the pH within normal limits.