Study Tip

Switch Tasks When you feel yourself losing focus, switch the type of task you are working on, the subject that you are studying, or the environment you are in. Take a break and walk around a bit. Stop studying when you are no longer being productive.

If your class subscribes to the Interactive Textbook with ChemASAP, your students can go online to access an interactive version of the Student Edition and a self-test.

**Chapter 8 Study Guide**

**Key Concepts**

8.1 Molecules and Molecular Compounds
- Molecular compounds tend to have relatively low melting and boiling points.
- A molecular formula shows how many atoms of each element a molecule contains.

8.2 The Nature of Covalent Bonding
- Electron sharing occurs so that atoms attain the configurations of noble gases.
- An electron dot structure shows the shared electrons of a covalent bond by a pair of dots.
- Atoms form double or triple bonds by sharing two or three pairs of electrons.
- In a coordinate covalent bond, the shared electron pair comes from a single atom.
- A large bond dissociation energy corresponds to a strong covalent bond.
- In ozone, the bonding of oxygen atoms is a hybrid of the extremes represented by the resonance forms.
- The octet rule is not satisfied in molecules with an odd number of electrons, and in molecules where an atom has less, or more, than a complete octet of valence electrons.

8.3 Bonding Theories
- Just as an atomic orbital belongs to a particular atom, a molecular orbital belongs to a molecule as a whole.
- According to VSEPR theory, the repulsion between electron pairs causes molecular shapes to adjust so that the valence-electron pairs stay as far apart as possible.
- Orbital hybridization provides information about both molecular bonding and molecular shape.

8.4 Polar Bonds and Molecules
- When different atoms bond, the more electronegative atom attracts electrons more strongly and acquires a slight negative charge.
- Polar molecules between oppositely charged metal plates tend to become oriented with respect to the positive and negative plates.
- Intermolecular attractions are weaker than either an ionic or covalent bond.
- Melting a network solid requires breaking covalent bonds throughout the solid.
- bond dissociation energy (p. 226)

**Vocabulary**

- bonding orbital (p. 230)
- covalent bond (p. 213)
- coordinate covalent bond (p. 223)
- diatomic molecule (p. 214)
- dipole (p. 239)
- dipole interactions (p. 240)
- dispersion forces (p. 240)
- double covalent bond (p. 221)
- hybridization (p. 234)
- hydrogen bonds (p. 241)
- molecular compound (p. 214)
- molecular formula (p. 215)
- molecular orbital (p. 230)
- molecule (p. 214)
- network solids (p. 243)
- nonpolar covalent bond (p. 237)
- pi bond (p. 231)
- polar bond (p. 238)
- polar covalent bond (p. 238)
- polar molecule (p. 239)
- polyatomic ion (p. 223)
- resonance structure (p. 227)
- sigma bond (p. 230)
- single covalent bond (p. 217)
- structural formula (p. 218)
- tetrahedral angle (p. 232)
- triple covalent bond (p. 221)
- unshared pair (p. 218)
- van der Waals forces (p. 240)
- VSEPR theory (p. 232)

**Organizing Information**

Construct a concept map that organizes the major ideas of this chapter.

**Chapter Resources**

**Print**
- Core Teaching Resources, Chapter 8
- Practice Problems, Vocabulary Review, Quiz, Chapter Test A, Chapter Test B

**Technology**
- Computer Test Bank, Chapter 8 Test
- Interactive Textbook with ChemASAP, Chapter 8
8.4 Polar Bonds and Molecules

57. How must the electronegativities of two atoms compare if a covalent bond between them is to be polar?
58. The bonds between the following pairs of elements are covalent. Arrange them according to polarity, naming the most polar bond first.
   a. H−Cl  b. H−C  c. H−F
   d. H−O  e. H−H  f. S−Cl
59. What is a hydrogen bond?
60. Describe the hydrogen bonding between two ammonia molecules and between one ammonia molecule and one water molecule.
61. Why do compounds with strong intermolecular attractive forces have higher boiling points than compounds with weak intermolecular attractive forces?
62. The 3s and three 3p orbitals of phosphorus hybridize to form four $sp^3$ atomic orbitals. The resulting shape is pyramidal with a bond angle of 107° between the sigma bonds.

63. The chlorine and oxygen atoms in thionyl chloride (SOCl$_2$) are bonded directly to the sulfur. Write an acceptable electron dot structure for thionyl chloride.

64. Explain why each electron dot structure is incorrect. Replace each structure with one that is more acceptable.

65. Use VSEPR theory to predict the geometry of each of the following.

   a. SiCl$_4$
   b. CO$_3^{2-}$
   c. CCl$_4$
   d. SCl$_2$

66. The following graph shows how the percent ionic character of a single bond varies according to the difference in electronegativity between the two elements forming the bond. Answer the following questions, using this graph and Table 6.1.

   a. What is the relationship between the percent ionic character of single bonds and the electronegativity difference of their elements?
   b. What electronegativity difference will result in a bond with a 50% ionic character?
   c. Estimate the percent ionic character of the bonds formed between (1) lithium and oxygen, (2) nitrogen and oxygen, (3) magnesium and chlorine, and (4) nitrogen and fluorine.

67. Give the angles between the orbitals of each hybrid.
   a. $sp^3$ hybrids
   b. $sp^2$ hybrids
   c. $sp$ hybrids

68. What is the geometry around the central atom in each of these simple molecules?

   a. 
   b. 
   c. 
   d. 

69. Which of the following molecules contains a central atom that does not obey the octet rule?

   a. PBr$_5$
   b. AlI$_3$
   c. PF$_3$
   d. SCl$_4$

70. Vinegar contains the compound ethanoic acid, whose molecular formula is CH$_3$COOH.

   a. Draw the electron dot structure of ethanoic acid.
   b. Is the bonding between each of the oxygen atoms and the carbon the same?
   c. Is the bonding between the carbon atom and each oxygen atom a polar or nonpolar bond?
   d. Is ethanoic acid a polar molecule?
Critical Thinking

71. Make a list of the elements found in Table 8.2 on page 224. What do the elements that form covalent bonds have in common?

72. Is there a clear difference between a very polar covalent bond and an ionic bond? Explain.

73. Although the relative positions of the atoms are correct in each of these molecules there are one or more incorrect bonds in each of the electron dot structures. Identify the incorrect bonds. Write the correct electron dot structure for each molecule.
   a. H≡C≡C≡H
   b. H—O—H
   c. H: 1 m: Cl:
   d. H—N::N—H

74. Ethyl alcohol and dimethyl ether each have the same molecular formula, C₂H₆O. Ethyl alcohol has a much higher boiling point (78°C) than dimethyl ether (–25°C). Propose an explanation for this difference.

75. What shape do you expect for a molecule with a central atom and the following?
   a. two bonding pairs of electrons and two non-bonding pairs of electrons.
   b. four bonding pairs and zero nonbonding pairs.
   c. three bonding pairs and one nonbonding pair.

76. Is this statement true or false? “As the electronegativity difference between covalently bonded atoms increases, the strength of the bond increases.” Use the table below to justify your answer.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Electronegativity Difference</th>
<th>Bond Dissociation Energy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C—C</td>
<td>2.5 – 2.5 = 0.0</td>
<td>347</td>
</tr>
<tr>
<td>C—H</td>
<td>2.5 – 2.1 = 0.4</td>
<td>393</td>
</tr>
<tr>
<td>C—N</td>
<td>3.0 – 2.5 = 0.5</td>
<td>305</td>
</tr>
<tr>
<td>C—O</td>
<td>3.5 – 2.5 = 1.0</td>
<td>356</td>
</tr>
</tbody>
</table>

77. The electron structure and geometry of the methane molecule (CH₄) can be described by a variety of models, including electron dot structure, simple overlap of atomic orbitals, and orbital hybridization of carbon. Write the electron dot structure of CH₄. Sketch two molecular orbital pictures of the CH₄ molecule. For your first sketch, assume that one of the paired 2s electrons of carbon has been promoted to the empty 2p orbital. Overlap each half-filled atomic orbital of carbon to a half-filled 2s orbital of hydrogen. What is the predicted geometry of the CH₄ molecule, using this simple overlap method? In your second sketch, assume hybridization of the 2s and 2p orbitals of carbon. Now what geometry would you predict for CH₄?

78. There are some compounds in which one atom has more electrons than the corresponding noble gas. Examples are PCl₅, SF₆, and IF₇. Write the electron dot structures of P, S, and I atoms and of these compounds. Considering the outer shell configuration of P, S, and I, develop an orbital hybridization scheme to explain the existence of these compounds.

79. Draw the electron dot structure of formic acid, H₂CO₂. The carbon is the central atom, and all the atoms are attached to the carbon except for a hydrogen bonded to an oxygen.

80. Oxalic acid, C₂H₂O₄, is used in polishes and rust removers. Draw the electron dot structure for oxalic acid given that the two carbons are bonded together but neither of the hydrogen atoms is bonded to a carbon atom.

81. Draw as many resonance structures as you can for HN₃. (Hint: the three nitrogen atoms are bonded in a row and the hydrogen atom is bonded to a nitrogen atom at the end of the row of nitrogens.)

82. Draw an electron dot structure for each molecule and explain why it fails to obey the octet rule.
   a. BeF₂ b. SiF₆ c. ClO₂ d. BF₃ e. XeF₂

Assessment 249

Concept Challenge

77. The first sketch shows carbon’s three p orbitals oriented at 90° angles, resulting in a pyramidal structure for the carbon atom with three hydrogen atoms. The 4th C-H bond, formed with carbon’s 2s orbital and a hydrogen atom’s 1s orbital, is at unspecified angles to the other three C-H bonds. The second sketch is tetrahedral. The bond angles in the first sketch are not all the same; some are 90°. The bond angles in the second sketch are all 109.5°. The second sketch is correct. (Note: The wedge-shaped lines come out of the page; the dotted lines recede into the page.)

71. C, O, H, S, N, F, Cl: These elements are all nonmetals.

72. Answers will vary. Table 8.3 suggests there is no clear difference. The student’s argument could be based on chemical properties, such as conductivity of the compound in the liquid state.

73. a. two covalent bonds to both carbons; double bond between carbons H—C≡C—H
   b. Fluorine and oxygen have only four electrons: F—O—F
   c. Halogens form one covalent bond, not three: F—Cl—F
   d. Nitrogen forms three covalent bonds, not four: H—N—N—H

74. Ethyl alcohol can form intermolecular hydrogen bonds between its polar –OH groups, but dimethyl ether can not form hydrogen bonds.

75. a. bent
   b. tetrahedral
   c. pyramidal

76. False. The bond dissociation energies exhibit no particular trend and, in fact, are fairly constant.
## Cumulative Review continued

### 83. Name three indicators of chemical change. (Chapter 2)

1. A change in color or odor
2. A change in physical properties
3. The formation of a gas

### 84. Make the following conversions. (Chapter 3)

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Unit</th>
<th>Equivalent Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 6.65 m</td>
<td>micro meters</td>
<td>6,650,000 μm</td>
</tr>
<tr>
<td>b. 4.67 g</td>
<td>centigrams</td>
<td>467 cg</td>
</tr>
<tr>
<td>c. 5.62 × 10⁻¹ decigram per liter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. 8.24 m/s</td>
<td>km/h</td>
<td>30.00 km/h</td>
</tr>
</tbody>
</table>

### 85. How many significant figures are in each measurement? (Chapter 3)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 0.00052 m</td>
<td>2</td>
</tr>
<tr>
<td>b. 9.8 × 10⁴ g</td>
<td>2</td>
</tr>
<tr>
<td>c. 5.750 mg</td>
<td>4</td>
</tr>
<tr>
<td>d. 8.700 mL</td>
<td>4</td>
</tr>
</tbody>
</table>

### 86. How many neutrons are in each atom? (Chapter 4)

<table>
<thead>
<tr>
<th>Element</th>
<th>Neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. silicon-30</td>
<td>15</td>
</tr>
<tr>
<td>b. magnesium-24</td>
<td>12</td>
</tr>
<tr>
<td>c. nitrogen-15</td>
<td>7</td>
</tr>
<tr>
<td>d. chromium-50</td>
<td>24</td>
</tr>
</tbody>
</table>

### 87. How do isotopes differ? (Chapter 4)

Isotopes have the same number of protons and electrons but different numbers of neutrons.

### 88. Protons and electrons must be equal.

#### a. 6
- b. 2
- c. 5
- d. 0

### 89. The wavelength decreases as the frequency increases.

#### a. 3
- b. 2
- c. 1
- d. 0

### 90. The d orbitals related to the third principal energy level contain 5 electrons.

<table>
<thead>
<tr>
<th>Subshell</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 1s²2s²2p⁶3s²3p⁶</td>
<td>12</td>
</tr>
<tr>
<td>b. 1s²2s²2p⁶3s²3p⁴</td>
<td>10</td>
</tr>
<tr>
<td>c. 1s²2s²2p⁶3s²3p³</td>
<td>9</td>
</tr>
<tr>
<td>d. 1s²2s²2p⁶</td>
<td>8</td>
</tr>
</tbody>
</table>

### 91. The anion is larger than the corresponding neutral atom.

#### a. 1
- b. 2
- c. 5
- d. 0

### 92. Mendeleev arranged the elements by increasing atomic mass in vertical rows and by similarities in chemical and physical properties.

#### a. potassium
- b. aluminum
- c. nitrogen
- d. chlorine

### 93. Which of these statements about the periodic table is correct? (Chapter 6)

- I. Elements are arranged in order of increasing atomic mass.
- II. A period is a horizontal row.
- III. Nonmetals are located on the right side of the table.

#### a. I only
- b. I and II only
- c. I, II, and III only
- d. I and III only
- e. II and III only

### 94. Isotopes have the same number of protons and electrons, but different numbers of neutrons.

**88. Protons and electrons must be equal.**

**89. The wavelength decreases as the frequency increases.**

**90. The d orbitals related to the third principal energy level contain 5 electrons.**

**91. The anion is larger than the corresponding neutral atom.**

**92. Mendeleev arranged the elements by increasing atomic mass in vertical rows and by similarities in chemical and physical properties.**

**93. Which of these statements about the periodic table is correct?**

- I. Elements are arranged in order of increasing atomic mass.
- II. A period is a horizontal row.
- III. Nonmetals are located on the right side of the table.

**94. Give the electron configuration of the element found at each location in the periodic table.**

**95. Give the electron configuration of the element found at each location in the periodic table.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Period</th>
<th>Electron Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 1s²2s²2p⁶</td>
<td>4</td>
<td>Group 1A, period 4</td>
</tr>
<tr>
<td>b. 1s²2s²2p⁶3s²3p⁶</td>
<td>3</td>
<td>Group 3A, period 3</td>
</tr>
<tr>
<td>c. 1s²2s²2p⁶3s²3p⁶3d¹⁰4s²</td>
<td>2</td>
<td>Group 2A, period 6</td>
</tr>
</tbody>
</table>

### 96. Identify the larger atom of each pair. (Chapter 6)

- a. calcium and barium
- b. silicon and sulfur
- c. sodium and nitrogen

### 97. Which of these ions has the same number of electrons as a noble gas? (Chapter 7)

- a. Al³⁺
- b. O²⁻
- c. Br⁻
- d. N⁰⁻

### 98. What element is likely to form an ionic compound with chlorine? (Chapter 7)

- a. iodine
- b. cesium
- c. helium

### 99. How many valence electrons does each atom have? (Chapter 7)

- a. argon
- b. aluminum
- c. selenium
- d. beryllium

### 100. Write the electron configuration of each ion. (Chapter 7)

- a. oxide ion
- b. magnesium ion
- c. nitride ion
- d. potassium ion

### 101. An alloy is composed of two or more elements. Is an alloy a compound? Explain your answer. (Chapter 7)
Covalent Bonding

1. A bond in which two atoms share a pair of electrons is not
   a. a coordinate covalent bond.
   b. a polar covalent bond.
   c. an ionic bond.
   d. a nonpolar covalent bond.

2. How many valence electrons are in a molecule of phosphoric acid, \(H_3PO_4\)?
   a. 7
   b. 16
   c. 24
   d. 32

3. Which of these molecules can form a hydrogen bond with a water molecule?
   a. \(N_2\)
   b. \(NH_3\)
   c. \(O_2\)
   d. \(CH_4\)

4. Which substance contains both covalent and ionic bonds?
   a. \(NH_3NO_3\)
   b. \(CH_3OCH_3\)
   c. \(LiF\)
   d. \(CaCl_2\)

5. Which of these bonds is most polar?
   a. \(H—Cl\)
   b. \(H—Br\)
   c. \(H—F\)
   d. \(H—I\)

Use the description and data table below to answer Questions 6–9.
The table relates molecular shape to the number of bonding and nonbonding electron pairs in molecules.

<table>
<thead>
<tr>
<th>Bonding pairs</th>
<th>Non-bonding pairs</th>
<th>Arrangement of electron pairs</th>
<th>Molecular shape</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
<td>tetrahedral</td>
<td>tetrahedral</td>
<td>(CH_4)</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>tetrahedral</td>
<td>pyramidal</td>
<td>(NCl_3)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>tetrahedral</td>
<td>bent</td>
<td>(H_2S)</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>tetrahedral</td>
<td>linear</td>
<td>(HF)</td>
</tr>
</tbody>
</table>

6. Draw the electron dot structure for each example molecule.

7. Explain why the arrangement of electron pairs is tetrahedral in each molecule.

8. \(H_2S\) has two hydrogen atoms bonded to a sulfur atom. Why isn’t the molecule linear?

9. What is the arrangement of electron pairs in \(PBr_3\)? Predict the molecular shape of a \(PBr_3\) molecule.

For Questions 10–12, identify the type of intermolecular bonding represented by the dotted lines in the drawings.

10. \(H_2O\)

11. \(BrCl\) (bromine chloride)

12. \(CH_3OH\) (methanol)

13. A carbon monoxide molecule has a triple covalent bond because carbon and oxygen atoms have an unequal number of valence electrons.

14. Xenon has a lower boiling point than neon because dispersion forces between xenon atoms are stronger than those between neon atoms.

15. The nitrate ion has three resonance structures because the nitrate ion has three single bonds.

In Questions 13–15, a statement is followed by an explanation. Decide if each statement is true and then decide if the explanation given is correct.

13. True
   False

14. False
   True

15. True
   False