If you learned only six things in this chapter...

1. Ionic bonding occurs between atoms with a large electronegativity difference, typically a metal and nonmetal. Atoms are held together by an electrostatic force defined by Coulomb's Law:

\[ E = 2.31 \times 10^{-19} f \cdot nm \left( \frac{Q_1 Q_2}{r} \right) \]

2. Covalent bonding takes place between atoms with a small electronegativity difference, and corresponds to an interaction in which electrons are shared. Lewis dot structures, in which the octet rule is generally obeyed, are used to represent covalent molecules.

3. Polarity refers to covalent molecules in which electrons are shared unequally, resulting in a net dipole moment when the molecule is placed in an electrical field. You must know the three-dimensional geometry of a molecule in order to predict polarity.

4. The VSEPR model is useful in predicting molecular geometry. This model states that the groups surrounding a central atom in a molecule generally want to be positioned as far apart as possible.

5. Using the VSEPR model, it's possible to predict the overall molecular geometry as well as the hybridization by looking at how many steric groups surround the central atom of a molecule.

6. The empirical formula of compounds can be determined by looking at the percent composition of their various elements. To determine the molecular formula (a multiple of the empirical formula), we will need to know the molar mass.
Chapter 8: 10, 12, 16, 22, 24, 26, 28, 32, 36, 38, 48, 50, 52, 54, 62, 64, 66, 68, 72, 73, 76, 78, 82, 84, 86, 90, 92, 100

Chapter 9: 22, 24, 26, 30, and 48

Chapter 8:
10. What is meant by a chemical bond? Why do atoms form bonds with each other? Why do some elements exist as molecules in nature instead of as free atoms?

12. Does a Lewis structure tell which electrons come from which atoms? Explain.

16. Explain the terms resonance and delocalization electrons

22. Predict the order of increasing electronegativity in each of the following groups of elements.
   a. Na, K, Rb
   b. B, O, Ga
   c. F, Cl, Br
   d. S, O, F

24. Predict which bond in each of the following groups will be the most polar.
   a. C-H, Si-H, Sn-H
   b. Al-Br, Ga-Br, In-Br, Tl-Br
   c. C-O or Si-O
   d. O-F or O-Cl

26. Repeat exercises 22 and 24, this time using the values for the electronegativities of the elements given in fig. 8.3. Are there differences in your answers?

28. Rank the following bonds in order of increasing ionic character: N-O, Ca-O, C-F, Br-Br, K-F.
32. What noble gas has the same electron configuration as each of the ions in the following compounds?
   a. Cesium sulfide
   b. Strontium fluoride
   c. Calcium nitride
   d. Aluminum bromide

36. For each of the following groups, place the atoms and/or ions in order of decreasing size.
   a. V, V$^{2+}$, V$^{3+}$, V$^{5+}$
   b. Na$^+$, K$^+$, Rb$^+$, Cs$^+$
   c. Te$^{2-}$, I$^-$, Cs$^+$, Ba$^{2+}$
   d. P, P$^-$, P$^2-$, P$^3-$
   e. O$^{2-}$, S$^{2-}$, Se$^{2-}$, Te$^{2-}$

38. Predict the empirical formulas of the ionic compounds formed from the following pairs of elements. Name each compound.
   a. Al and Cl
   b. Na and O
   c. Sr and F
   d. Ca and P

48. Use bond energy values to estimate $\Delta H$ for each of the following reactions
   a. $\text{H} \cdot \text{C} \cdot \text{N(g)} + 2\text{H}_2(g) \rightarrow \text{H} \cdot \text{C} \cdot \text{N(g)}$
   b. $\text{H} \cdot \text{N} \cdot \text{N} \cdot \text{H(g)} + 2\text{F}_2(g) \rightarrow \text{N} \cdot \text{N} \cdot \text{N(g)} + 4\text{HF(g)}$
50. Acetic acid is responsible for the sour taste of vinegar. It can be manufactured using the following reaction:

\[
\text{CH}_3\text{OH}(g) + \text{C} \longrightarrow \text{O}(g) \rightarrow \text{CH}_3\text{C} \longrightarrow \text{OH}(l)
\]

Use tabulated values of bond energies to estimate \(\Delta H\) for this reaction.

52. The space shuttle orbiter utilizes the oxidation of methyl hydrazine by dinitrogen tetroxide for propulsion:

\[
5\text{N}_2\text{O}_4(l) + 4\text{N}_2\text{H}_3\text{CH}_3(l) \rightarrow 12\text{H}_2\text{O}(g) + 9\text{N}_2(g) + 4\text{CO}_2(g)
\]

Use bond energies to estimate \(\Delta H\) for this reaction. The structures for the reactants are:

![Reactant structures](image)

54. Consider the following reaction:

Estimate the carbon-fluorine bond energy given that the C-C bond energy is 347 kJ/mol, the C=C bond energy is 614 kJ/mol, and the F-F bond energies 154 kJ/mol.
62. Write Lewis structures that obey the octet rule for each of the following molecules and ions. (In each case the first atom listed is the central atom.)
   a. POCl$_3$, SO$_4^{2-}$, XeO$_4$, PO$_4^{3-}$, ClO$_4^-$
   b. NF$_3$, SO$_3^{2-}$, PO$_3^{3-}$, ClO$_3^-$
   c. ClO$_2^-$, SCl$_2$, PCl$_2^-$
   d. Considering our answers for parts a, b, c, what conclusions can you draw concerning the structures of species containing the same number of atoms and the same number of valence electrons?

64. ClF$_3$ and BrF$_3$ are both used to fluorinate uranium to produce UF$_6$ in the procession and reprocessing of nuclear fuel. Write Lewis structures for ClF$_3$ and BrF$_3$. 

66. Some of the important pollutants in the atmosphere are ozone (O₃), sulfur dioxide, and sulfur trioxide. Write Lewis structures for these three molecules. Show all resonance structures where applicable.

68. Borazine (B₃N₃H₆) has often been called “inorganic” benzene. Write Lewis structures for borazine. Borazine contains a six membered ring of alternating boron and nitrogen atoms with one hydrogen bonded to each boron and nitrogen.

72. Order the following species with respect to carbon-oxygen bond length (longest to shortest).

\[ \text{CO, CO}_2, \text{CO}_3^{2-}, \text{CH}_3\text{OH} \]

What is the order from the weakest to the strongest carbon-oxygen bond?

73. Write Lewis structures that obey the octet rule for the following species. Assign the formal charge for each central atom.
   a. POCl₃
   b. SO₄²⁻
   c. ClO₄⁻
   d. PO₄³⁻
   e. SO₂Cl₂
   f. XeO₄
76. Oxidation of the cyanide ion produces the stable cyanate ion, OCN⁻. The fulminate ion, CNO⁻, on the other hand, is very unstable. Fulminate salts explode when struck: Hg(CNO)₂ is used in blasting caps. Write the Lewis structures and assign formal charges for the cyanate and fulminate ions. Why is the fulminate ion so unstable? (C is the central atom in OCN⁻ and N is the central atom in CNO⁻)

78. Predict the molecular structure and bond angles for each molecule or ion in exercises 62 and 66.

82. Predict the molecular structure (including bond angles) for each of the following.
   a. PCl₃
   
   b. SCl₂
   
   c. SiF₄
84. Predict the molecular structure (including bond angles) for each of the following
   a. $\text{ICl}_5$

   b. $\text{XeCl}_4$

   c. $\text{SeCl}_6$

86. Which of the molecules in Exercise 82 have dipole moments (are polar)?

90. Write Lewis structures and predict whether each of the following is polar or nonpolar.
   a. $\text{HOCN}$ (exists as HO-CN)

   b. COS

   c. $\text{XeF}_2$

   d. $\text{CF}_2\text{Cl}_2$

   e. $\text{SeF}_6$

   f. $\text{H}_2\text{CO}$ (C is the central atom.)
92. Consider the following Lewis structure where E is an unknown element:

\[
\begin{array}{c}
\vdots \\
F^- & \vdots & \vdots \\
\vdots & \vdots \\
\vdots & \vdots \\
\vdots & \vdots
\end{array}
\]

What are some possible identities for element E? Predict the molecular structure (including bond angles) for this ion.

100. Lewis structures can be used to understand why some molecules react in certain ways. Write the Lewis structures for the reactants and products in the reactions described below.

a. Nitrogen dioxide dimerizes to produce dinitrogen tetroxide.

\[
\text{Nitrogen dioxide} \rightarrow \text{Dinitrogen tetroxide}
\]

b. Boron trifluoride accepts a pair of electrons from ammonia, forming BF\(_3\)NH\(_3\).

\[
\text{BF}_3 + \text{NH}_3 \rightarrow \text{BF}_3\text{NH}_3
\]

Chapter 9:

22. For each of the following molecules or ions that contain sulfur, write the Lewis structure(s), predict the molecular structure (including bond angles), and give the expected hybrid orbitals for sulfur.

a. SO\(_2\)

\[
\text{SO}_2
\]

b. SO\(_3\)

\[
\text{SO}_3^{2-}
\]

c. S\(_2\)O\(_3^{2-}\)

\[
\text{S}_2\text{O}_3^{2-}
\]
d. $\text{SO}_3^2$  

\[ S_2\text{O}_8^2 \]

\[ \text{O} - \text{S} - \text{O} - \text{S} - \text{O} - \text{O} - \text{S} - \text{O} \]

e. $\text{SO}_3^2$  

f. $\text{SO}_4^{2-}$  

g. $\text{SF}_2$  

h. $\text{SF}_4$
24. The allene molecule has the following Lewis structure:

\[
\begin{array}{c}
\text{H} \\
\text{C} - \text{C} - \text{C} \\
\text{H} \\
\end{array}
\]

Are all four hydrogen atoms in the same plane? If not, what is their special relationship? Explain.
26. Many important compounds in the chemical industry are derivatives of ethylene (C\textsubscript{2}H\textsubscript{4}). Two of them are acrylonitrile and methyl methacrylate.

\[
\begin{align*}
\text{Acrylonitrile} & : \quad \text{H} - & & - & & \text{H} \\
\text{Methyl methacrylate} & : \quad \text{H} & & _d C & & \text{CH}_3 \\
\end{align*}
\]

Complete the Lewis structures, showing all lone pairs. Give approximate values for bond angles a through f. Give the hybridization of all carbon atoms. In acrylonitrile, how many \(\sigma\) bonds and how many \(\pi\) bonds are there in methyl methacrylate and acrylonitrile?

30. The three most stable oxides of carbon are carbon monoxide (CO), carbon dioxide (CO\textsubscript{2}), and carbon suboxide (C\textsubscript{3}O\textsubscript{2}). The space-filling models for these three compounds are

\[
\begin{align*}
\text{Carbon monoxide} & \quad \text{Carbon dioxide} & \quad \text{Carbon suboxide} \\
\end{align*}
\]

For each oxide, draw the Lewis structure, predict the molecular structure, and describe the bonding (in terms of the hybrid orbitals for the carbon atoms).

48. FC\textsubscript{1}O\textsubscript{2} and F\textsubscript{3}ClO can both gain a fluoride ion to form stable anions. F\textsubscript{3}ClO and FC\textsubscript{1}O\textsubscript{2} will both lose a fluoride ion to form stable cations. Draw the Lewis structures and describe the hybrid orbitals used by chlorine in these ions.