Pearson

Exercises

Review Questions

1. What is electronegativity? What are the periodic trends in electronegativity?
2. Explain the difference between a pure covalent bond, a polar covalent bond, and an ionic bond.
3. What is meant by the percent ionic character of a bond? Do any bonds have 100% ionic character?
4. What is a dipole moment?
5. What is the magnitude of the dipole moment formed by separating a proton and an electron by 100 pm? 200 pm?
6. What is the basic procedure for writing a covalent Lewis structure?
7. How do you determine the number of electrons that go into the Lewis structure of a molecule? A polyatomic ion?
8. What are resonance structures? What is a resonance hybrid?
9. Do resonance structures always contribute equally to the overall structure of a molecule? Explain.
10. What is formal charge? How is formal charge calculated? How is it helpful?
11. Why does the octet rule have exceptions? Give the three major categories of exceptions and an example of each.
12. Which elements can have expanded octets? Which elements cannot have expanded octets?
13. What is bond energy?
14. Give some examples of some typical bond lengths. Which factors influence bond lengths?
15. Why is molecular geometry important? Cite some examples.
16. According to VSEPR theory, what determines the geometry of a molecule?
17. Name and draw the five basic electron geometries, and state the number of electron groups corresponding to each. What constitutes an *electron group*?
18. Explain the difference between electron geometry and molecular geometry. Under what circumstances are they not the same?
19. List the correct electron and molecular geometries that correspond to each set of electron groups around the central atom of a molecule.
    a. four electron groups overall; three bonding groups and one lone pair
    b. four electron groups overall; two bonding groups and two lone pairs
    c. five electron groups overall; four bonding groups and one lone pair
    d. five electron groups overall; three bonding groups and two lone pairs
    e. five electron groups overall; two bonding groups and three lone pairs
    f. six electron groups overall; five bonding groups and one lone pair
    g. six electron groups overall; four bonding groups and two lone pairs
20. How do you apply VSEPR theory to predict the shape of a molecule with more than one interior atom?
21. How do you determine if a molecule is polar?
22. Why is polarity a key connection between the structure of a molecule and its properties?

Problems by Topic

Note: Answers to all odd-numbered Problems can be found in Appendix III. Exercises in the Problems by Topic section are paired, with each odd-numbered problem followed by a similar even-numbered problem. Exercises in the Cumulative Problems section are also paired but somewhat more loosely. Because of their nature, Challenge Problems and Conceptual Problems are unpaired.

Electronegativity and Bond Polarity

23. Determine if a bond between each pair of atoms would be pure covalent, polar covalent, or ionic.

- **a.** Br and Br
- **b.** C and Cl
- **c.** C and S
- **d.** Sr and O

24. Determine if a bond between each pair of atoms would be pure covalent, polar covalent, or ionic.

- **a.** C and N
- **b.** N and S
- **c.** K and F
- **d.** N and N

25. Draw the Lewis structure for CO with an arrow representing the dipole moment. Use Figure 5.5 to estimate the percent ionic character of the CO bond.

26. Draw the Lewis structure for BrF with an arrow representing the dipole moment. Use Figure 5.5 to estimate the percent ionic character of the BrF bond.

Writing Lewis Structures, Resonance, and Formal Charge

27. Write the Lewis structure for each molecule.

- **a.** PH_3
- **b.** SCl_2
- **c.** HI
- **d.** CH_4

28. Write the Lewis structure for each molecule.

- **a.** NF_3
- **b.** HBr
- **c.** SBr_2
- **d.** CCl_4

29. Write the Lewis structure for each molecule.

- **a.** SF_2
- **b.** SiH_4
- **c.** HCOOH (both O bonded to C)
- **d.** CH_3SH (C and S central)

30. Write the Lewis structure for each molecule.

- **a.** CH_2O
- **b.** C_2Cl_4

31. Write the Lewis structure for each molecule or ion.

- **a.** CI_4
- **b.** N_2O
- **c.** SiH_4
- **d.** Cl_2CO

32. Write the Lewis structure for each molecule or ion.

- **a.** H_3COH
- **b.** OH^-
- **c.** BrO^-
- **d.** $O_2{}^{2-}$

33. Write the Lewis structure for each molecule or ion.

- **a.** N_2H_2
- **b.** N_2H_4
- **c.** C_2H_2
- **d.** C_2H_4

34. Write the Lewis structure for each molecule or ion.

- **a.** H_3COCH_3
- **b.** CN^-
- **c.** $NO_2{}^-$
- **d.** ClO^-

35. Write a Lewis structure that obeys the octet rule for each molecule or ion. Include resonance structures if necessary and assign formal charges to each atom.

a. SeO_2

b. CO_3^{2-}

c. ClO^-

d. NO_2^-

36. Write a Lewis structure that obeys the octet rule for each ion. Include resonance structures if necessary and assign formal charges to each atom.

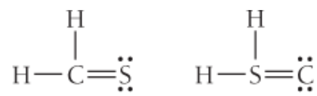
a. ClO_3^-

b. ClO_4^-

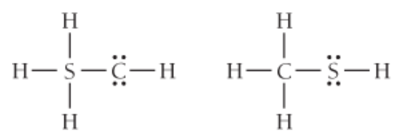
c. NO_3^-

d. NH_4^+

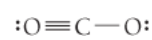
37. Use formal charge to determine which Lewis structure is better.



38. Use formal charge to determine which Lewis structure is better.



39. How important is this resonance structure to the overall structure of carbon dioxide? Explain.

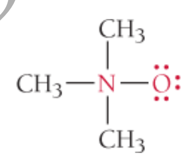


40. In N_2O, nitrogen is the central atom and the oxygen atom is terminal. In OF_2, however, oxygen is the central atom. Use formal charges to explain why.

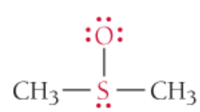
41. Draw the Lewis structure (including resonance structures) for the acetate ion (CH_3COO^-). For each resonance structure, assign formal charges to all atoms that have formal charge.

42. Draw the Lewis structure (including resonance structures) for methyl azide (CH_3N_3). For each resonance structure, assign formal charges to all atoms that have formal charge.

43. Determine the formal charges of the atoms shown in red.



44. Determine the formal charges of the atoms shown in red.



Odd-Electron Species, Incomplete Octets, and Expanded Octets

45. Write the Lewis structure for each molecule (octet rule not followed).

a. BCl_3

b. NO_2

c. BH_3

46. Write the Lewis structure for each molecule (octet rule not followed).

a. BBr_3

b. NO

c. ClO_2

47. Write the Lewis structure for each ion. Include resonance structures if necessary and assign formal charges to all atoms. If necessary, expand the octet on the central atom to lower formal charge.

all atoms. If necessary, expand the octet on the central atom to lower formal charge.

a. $PO_4{}^{3-}$

b. CN^-

c. $SO_3{}^{2-}$

d. $ClO_2{}^-$

48. Write Lewis structures for each molecule or ion. Include resonance structures if necessary and assign formal charges to all atoms. If you need to, expand the octet on the central atom to lower formal charge.

a. $SO_4{}^{2-}$

b. $HSO_4{}^-$

c. SO_3

d. $BrO_2{}^-$

49. Write Lewis structures for each molecule or ion. Use expanded octets as necessary.

a. PF_5

b. $I_3{}^-$

c. SF_4

d. GeF_4

50. Write Lewis structures for each molecule or ion. Use expanded octets as necessary.

a. ClF_5

b. $AsF_6{}^-$

c. Cl_3PO

d. IF_5

Bond Energies and Bond Lengths

51. List these compounds in order of increasing carbon–carbon bond *strength* and in order of decreasing carbon–carbon bond *length*: $HCCH, H_2CCH_2, H_3CCH_3$.

52. Which of these compounds has the stronger nitrogen–nitrogen bond? The shorter nitrogen–nitrogen bond?

$$H_2NNH_2, HNNH$$

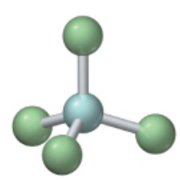
VSEPR Theory and Molecular Geometry

53. A molecule with the formula AB_3 has a trigonal pyramidal geometry. How many electron groups are on the central atom (A)?

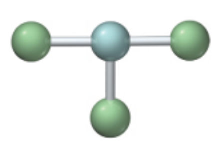
54. A molecule with the formula AB_3 has a trigonal planar geometry. How many electron groups are on the central atom?

55. For each molecular geometry shown here, list the number of total electron groups, the number of bonding groups, and the number of lone pairs on the central atom.

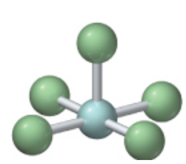
a.



b.

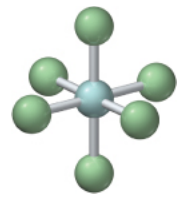


c.

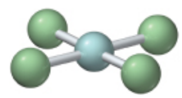


56. For each molecular geometry shown here, list the number of total electron groups, the number of bonding groups, and the number of lone pairs on the central atom.

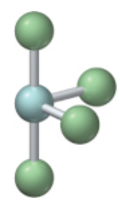
a.



b.



c.



57. Determine the electron geometry, molecular geometry, and idealized bond angles for each molecule. In which cases do you expect deviations from the idealized bond angle?

a. PF_3

b. SBr_2

c. $CHCl_3$

d. CS_2

58. Determine the electron geometry, molecular geometry, and idealized bond angles for each molecule. In which cases do you expect deviations from the idealized bond angle?

a. CF_4

b. NF_3

c. OF_2

d. H_2S

59. Which species has the smaller bond angle, H_3O^+ or H_2O? Explain.

60. Which species has the smaller bond angle, ClO_4^- or ClO_3^-? Explain.

61. Determine the molecular geometry and draw each molecule or ion using the bond conventions shown in the "Representing Molecular Geometries on Paper" section of this chapter (see Section 5.9).

a. SF_4

b. ClF_3

c. IF_2^-

d. IBr_4^-

62. Determine the molecular geometry and draw each molecule or ion, using the bond conventions shown in the "Representing Molecular Geometries on Paper" section of this chapter (see Section 5.9).

a. BrF_5

b. SCl_6

c. PF_5

d. IF_4^+

63. Determine the molecular geometry about each interior atom and draw each molecule. (Skeletal structure is indicated in parentheses.)

a. C_2H_2 (HCCH)

b. C_2H_4 (H_2CCH_2)

c. C_2H_6 (H_3CCH_3)

64. Determine the molecular geometry about each interior atom and draw each molecule. (Skeletal structure is indicated in parentheses.)

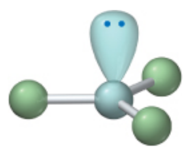
a. N_2

b. N_2H_2 $(HNNH)$

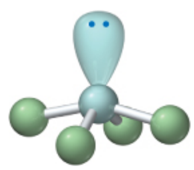
c. N_2H_4 (H_2NNH_2)

65. Each ball-and-stick model incorrectly shows the electron and molecular geometry of a generic molecule. Explain what is wrong with each molecular geometry and provide the correct molecular geometry, given the number of lone pairs and bonding groups on the central atom.

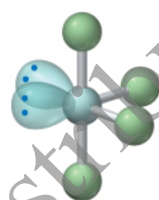
a.



b.

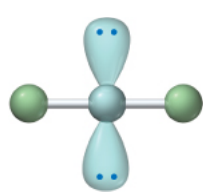


c.

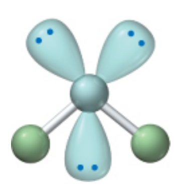


66. Each ball-and-stick model incorrectly shows the electron and molecular geometry of a generic molecule. Explain what is wrong with each molecular geometry and provide the correct molecular geometry, given the number of lone pairs and bonding groups on the central atom.

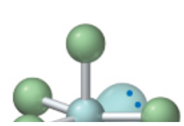
a.

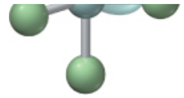


b.



c.





67. Determine the geometry about each interior atom in each molecule and draw the molecule. (Skeletal structure is indicated in parentheses.)

a. CH_3OH (H_3COH)

b. CH_3OCH_3 (H_3COCH_3)

c. H_2O_2 $(HOOH)$

68. Determine the geometry about each interior atom in each molecule and draw the molecule. (Skeletal structure is indicated in parentheses.)

a. CH_3NH_2 (H_3CNH_2)

b. $CH_3CO_2CH_3$ ($H_3CCOOCH_3$ both O atoms attached to second C)

c. NH_2CO_2H (H_2NCOOH both O atoms attached to C)

Molecular Shape and Polarity

69. Explain why CO_2 and CCl_4 are both nonpolar, even though they contain polar bonds.

70. CH_3F is a polar molecule, even though the tetrahedral geometry often leads to nonpolar molecules. Explain.

71. Determine whether each molecule in Exercise 57 is polar or nonpolar.

72. Determine whether each molecule in Exercise 58 is polar or nonpolar.

73. Determine whether each molecule or ion is polar or nonpolar.

a. $ClO_3{}^-$

b. SCl_2

c. SCl_4

d. $BrCl_5$

74. Determine whether each molecule is polar or nonpolar.

a. $SiCl_4$

b. CF_2Cl_2

c. SeF_6

d. IF_5

Cumulative Problems

75. Each compound contains both ionic and covalent bonds. Write ionic Lewis structures for each, including the covalent structure for the ion in brackets. Write resonance structures if necessary.

a. $BaCO_3$

b. $Ca(OH)_2$

c. KNO_3

d. $LiIO$

76. Each compound contains both ionic and covalent bonds. Write ionic Lewis structures for each, including the covalent structure for the ion in brackets. Write resonance structures if necessary.

a. $RbIO_2$

b. NH_4Cl

c. KOH

d. $Sr(CN)_2$

77. Carbon ring structures are common in organic chemistry. Draw a Lewis structure for each carbon ring structure, including any necessary resonance structures.

a. C_4H_8

b. C_4H_4

c. C_6H_{12}

d. C_6H_6

78. Amino acids are the building blocks of proteins. The simplest amino acid is glycine (H_2NCH_2COOH). Draw a Lewis structure for glycine. (*Hint*: The central atoms in the skeletal structure are nitrogen bonded to carbon, which is bonded to another carbon. The two oxygen atoms are bonded directly to the rightmost carbon atom.)

79. Formic acid is partly responsible for the sting of ant bites. By mass, formic acid is 26.10% C, 4.38% H, and

69.52% O. The molar mass of formic acid is 46.02 g/mol. Find the molecular formula of formic acid and draw its Lewis structure.

80. Diazomethane is a highly poisonous, explosive compound because it readily evolves N_2. Diazomethane has the following composition by mass: 28.57% C; 4.80% H; and 66.64% N. The molar mass of diazomethane is 42.04 g/mol. Find the molecular formula of diazomethane, draw its Lewis structure, and assign formal charges to each atom. Why is diazomethane not very stable? Explain.

81. Draw the Lewis structure for nitric acid (the hydrogen atom is attached to one of the oxygen atoms). Include all three resonance structures by alternating the double bond among the three oxygen atoms. Use formal charge to determine which of the resonance structures is most important to the structure of nitric acid.

82. Phosgene (Cl_2CO) is a poisonous gas that was used as a chemical weapon during World War I. It is a potential agent for chemical terrorism today. Draw the Lewis structure of phosgene. Include all three resonance forms by alternating the double bond among the three terminal atoms. Which resonance structure is the best?

83. The cyanate ion (OCN^-) and the fulminate ion (CNO^-) share the same three atoms but have vastly different properties. The cyanate ion is stable, while the fulminate ion is unstable and forms explosive compounds. The resonance structures of the cyanate ion were explored in Example 5.6. Draw Lewis structures for the fulminate ion—including possible resonance forms—and use formal charge to explain why the fulminate ion is less stable (and therefore more reactive) than the cyanate ion.

84. Draw the Lewis structure for each organic compound from its condensed structural formula.

a. C_3H_8

b. CH_3OCH_3

c. CH_3COCH_3

d. CH_3COOH

e. CH_3CHO

85. Draw the Lewis structure for each organic compound from its condensed structural formula.

a. C_2H_4

b. CH_3NH_2

c. HCHO

d. CH_3CH_2OH

e. HCOOH

86. Use Lewis structures to explain why $Br_3{}^-$ and $I_3{}^-$ are stable, while $F_3{}^-$ is not.

87. Draw the Lewis structure for $HCSNH_2$. (The carbon and nitrogen atoms are bonded together, and the sulfur atom is bonded to the carbon atom.) Label each bond in the molecule as polar or nonpolar.

88. Draw the Lewis structure for urea, H_2NCONH_2, one of the compounds responsible for the smell of urine. (The central carbon atom is bonded to both nitrogen atoms and to the oxygen atom.) Does urea contain polar bonds? Which bond in urea is most polar?

89. Some theories of aging suggest that free radicals cause certain diseases and perhaps aging in general. As you know from the Lewis model, such molecules are not chemically stable and will quickly react with other molecules. According to some theories, free radicals may attack molecules within the cell, such as DNA, changing them and causing cancer or other diseases. Free radicals may also attack molecules on the surfaces of cells, making them appear foreign to the body's immune system. The immune system then attacks the cells and destroys them, weakening the body. Draw Lewis structures for the free radicals implicated in this theory of aging, which are given here.

a. $O_2{}^-$

b. O^-

c. OH

d. CH_3OO (unpaired electron on terminal oxygen)

90. Free radicals are important in many environmentally significant reactions. For example, photochemical smog—smog that results from the action of sunlight on air pollutants—forms in part by these two steps:

$$NO_2 \xrightarrow{\text{UV light}} NO + O$$
$$O + O_2 \longrightarrow O_3$$

The product of this reaction, ozone, is a pollutant in the lower atmosphere. (Upper atmospheric ozone is a natural part of the atmosphere that protects life on Earth from ultraviolet light.) Ozone is an eye and lung irritant and also accelerates the weathering of rubber products. Rewrite the above reactions using the Lewis structure of each reactant and product. Identify the free radicals.

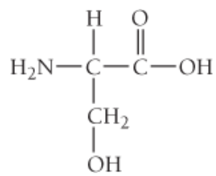
structure of each reactant and product. Identify the free radicals.

91. A compound composed of only carbon and hydrogen is 7.743% hydrogen by mass. Draw a Lewis structure for the compound.

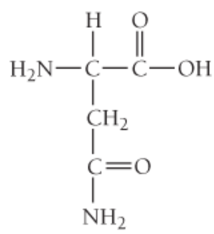
92. A compound composed of only carbon and chlorine is 85.5% chlorine by mass. Draw a Lewis structure for the compound.

93. Amino acids are biological compounds that link together to form proteins, the workhorse molecules in living organisms. The skeletal structures of several simple amino acids are shown here. For each skeletal structure, complete the Lewis structure, determine the geometry about each interior atom, and draw the molecule, using the bond conventions of Section 5.9.

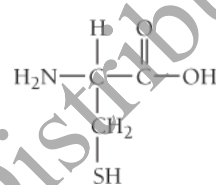
a. serine



b. asparagine



c. cysteine



94. The genetic code is based on four different bases with the structures shown here. Assign a geometry to each interior atom in these four bases.

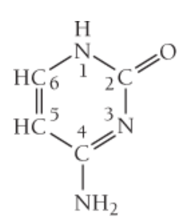
a. cytosine

b. adenine

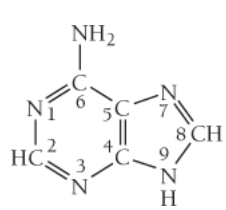
c. thymine

d. guanine

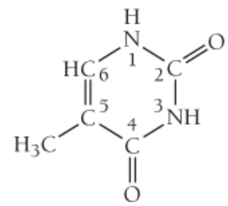
a.



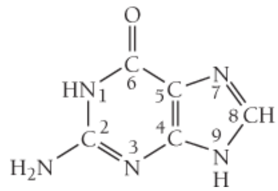
b.



c.

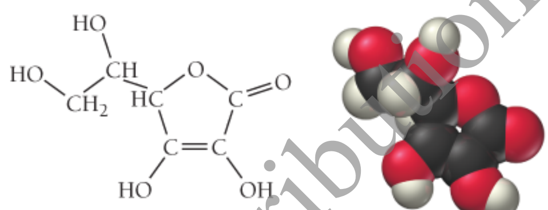


d.

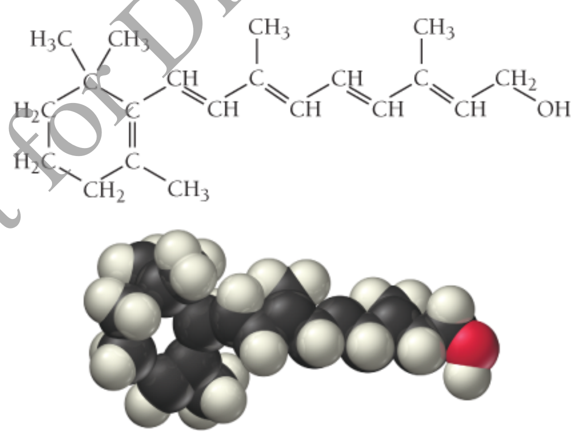


95. Most vitamins can be classified either as fat soluble, which results in their tendency to accumulate in the body (so that taking too much can be harmful), or water soluble, which results in their tendency to be quickly eliminated from the body in urine. Examine the structural formulas and space-filling models of these vitamins and determine whether each one is fat soluble (mostly nonpolar) or water soluble (mostly polar).

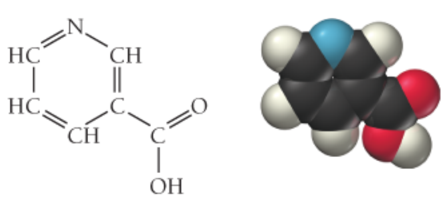
a. vitamin C



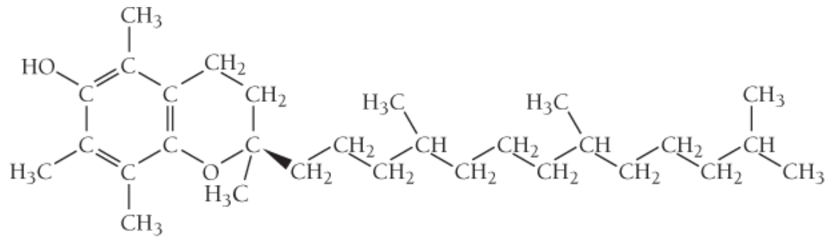
b. vitamin A

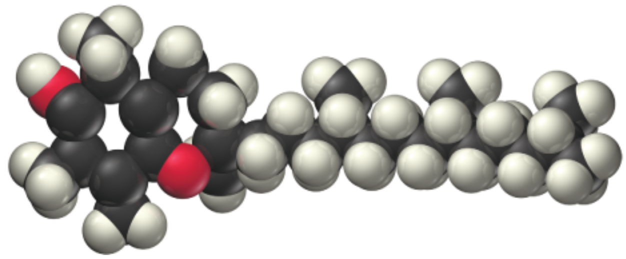


c. niacin (vitamin B_3)

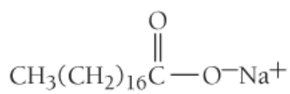


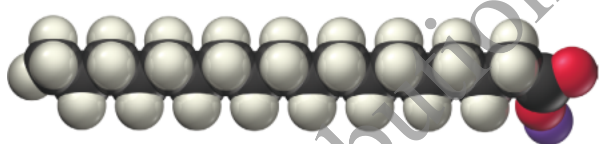
d. vitamin E





96. Water alone does not easily remove grease from dishes or hands because grease is nonpolar and water is polar. The addition of soap to water, however, allows the grease to dissolve. Study the structure of sodium stearate (a soap) and describe how its structure allows it to interact with both nonpolar grease and polar water.





Challenge Problems

97. The azide ion, N_3^-, is a symmetrical ion, and all of its contributing resonance structures have formal charges. Draw three important contributing structures for this ion.
98. A 0.167-g sample of an unknown compound contains 0.00278 mol of the compound. Elemental analysis of the compound gives the following percentages by mass: 40.00% C; 6.71% H; 53.29% O. Determine the molecular formula, molar mass, and Lewis structure of the unknown compound.
99. Use the dipole moments of HF and HCl (given at the end of the problem) together with the percent ionic character of each bond (Figure 5.5) to estimate the bond length in each molecule. How well does your estimated bond length agree with the bond length in Table 5.4?

$$\begin{aligned} \text{HCl}\ \mu &= 1.08\ \text{D} \\ \text{HF}\ \mu &= 1.82\ \text{D} \end{aligned}$$

100. One form of phosphorus exists as P_4 molecules. Each P_4 molecule has four equivalent P atoms, no double or triple bonds, and no expanded octets. Draw the Lewis structure for P_4.
101. A compound has the formula C_8H_8 and does not contain any double or triple bonds. All the carbon atoms are chemically identical, as are all the hydrogen atoms. Draw the Lewis structure for this molecule.
102. Draw the Lewis structure for acetamide (CH_3CONH_2), an organic compound, and determine the geometry about each interior atom. Experiments show that the geometry about the nitrogen atom in acetamide is nearly planar. Which resonance structure can account for the planar geometry about the nitrogen atom?
103. Use VSEPR to predict the geometry (including bond angles) about each interior atom of methyl azide (CH_3N_3) and draw the molecule. Would you expect the bond angle between the two interior nitrogen atoms to be the same or different? Would you expect the two nitrogen–nitrogen bond lengths to be the same or different?

Conceptual Problems

104. In the very first chapter of this book, we described the scientific approach and put a special emphasis on scientific models or theories. In this chapter, we looked carefully at the Lewis model of chemical bonding. Why is this theory successful? What are some of the limitations of the theory?

105. Which statement best captures the fundamental idea behind VSEPR theory? Explain what is wrong with the statements you do not choose.

a. The angle between two or more bonds is determined primarily by the repulsions between the electrons within those bonds and other (lone pair) electrons on the central atom of a molecule. Each of these electron groups (bonding electrons or lone pair electrons) lowers its potential energy by maximizing its separation from other electron groups, thus determining the geometry of the molecule.

b. The angle between two or more bonds is determined primarily by the repulsions between the electrons within those bonds. Each of these bonding electrons lowers its potential energy by maximizing its separation from other electron groups, thus determining the geometry of the molecule.

c. The geometry of a molecule is determined by the shapes of the overlapping orbitals that form the chemical bonds. Therefore, to determine the geometry of a molecule, you must determine the shapes of the orbitals involved in bonding.

106. Suppose that a molecule has four bonding groups and one lone pair on the central atom. Suppose further that the molecule is confined to two dimensions (this is a purely hypothetical assumption for the sake of understanding the principles behind VSEPR theory). Draw the molecule and estimate the bond angles.

Questions for Group Work

Active Classroom Learning

Discuss these questions with the group and record your consensus answer.

107. Have each member of your group represent an atom of a metal or an atom of a nonmetal. Each group member holds a coin to represent an electron. Which group members are most reluctant to give up their electrons? Which group members are most willing to give up their electrons? Determine which kind of bond could form between each pair of group members. Tabulate your results.

108. Spend a few minutes reviewing the Lewis symbols for the atoms H through Ne. Form a circle and have each group member ask the group member on his or her right to draw the Lewis symbol for a specific atom. Keep going around until each group member can write all the Lewis dot symbols for the atoms H through Ne. Determine the formal charge for each symbol. In a complete sentence or two, describe why the formal charges are all the same.

109. Draw the Lewis symbols for the atoms Al and O. Use the Lewis model to determine the formula for the compound that forms from these two atoms.

110. Draft a list of step-by-step instructions for writing the correct Lewis structure for any molecule or polyatomic ion.

111. Pass a piece of paper around the group and ask each group member in turn to perform the next step in the process of determining a correct Lewis structure (including formal charges on all atoms and resonance structures, if appropriate) for the following molecules and ions: $N_2H_4, CCl_4, CO_3{}^{2-}$, and $NH_4{}^{+}$.

112. In complete sentences, describe why someone might expect the bond angles in methane (CH_4) to be 90°, although the bonds are actually 109.5°.

113. At least two different numbers of electron groups can result in a linear molecule. What are they? What are the numbers of bonding groups and lone pairs in each case? Provide an example of a linear molecule in each case.

114. Have each member of your group select one of the molecules and complete steps a–d. Have members present their results to the rest of the group, explaining the reasoning they used to determine their answers.

$$CS_2 \quad NCl_3 \quad CF_4 \quad CH_2F_2$$

a. Draw the Lewis structure.

b. Determine the molecular geometry and draw it accurately.

c. Indicate the polarity of any polar bonds within the structure.

d. Classify the molecule as polar or nonpolar.

Data Interpretation and Analysis

115. The VSEPR model is useful in predicting bond angles for many compounds. However, as we have seen, other factors (such as type of bond and atomic radii) may also influence bond angles. Consider that data for bond angles in related species in the tables and answer the questions.

Bond Angles in NO_2 and Associated Ions

Species	Bond Angle
NO_2	134°
NO_2^+	180°
NO_2^-	115°

Bond Angles in PX_3 Compounds

Compounds	Bond Angle
PH_3	94°
PF_3	97°
PCl_3	100°
PI_3	102°

a. Draw Lewis structures for all of the species in the Bond Angles in NO_2 and Associated Ions Table.

b. Use the Lewis structures from part (a) to explain the observed bond angles in NO_2 and its associated ions.

c. Draw Lewis structures for all of the species in the Bond Angles in PX_3 Compounds Table.

d. Make your own table showing the atomic radii of H, F, Cl, and I.

e. Use your answers to parts (c) and (d) to explain the observed bond angles in PH_3, PF_3, PCl_3, and PI_3.

Answers to Conceptual Connections

Cc 5.1 N > P > Al > Na

Cc 5.2 **(b)** The dipole moment of the HCl bond is about 1 D, and the bond length is 127 pm. Previously you calculated the dipole moment for a 130-pm bond that is 100% ionic to be about 6.2 D. You can therefore estimate the bond's ionic character as $\frac{1}{6} \times 100\%$, which is closest to 15%.

Cc 5.3 **(d)** ClO because the sum of its valence electrons is odd.

Cc 5.4 **(b)** The only molecule in this group that could have an expanded octet is H_3PO_4 because phosphorus is a third-period element. Expanded octets *never* occur in second-period elements such as carbon and nitrogen.

Cc 5.5 The geometry of a molecule is determined by how the terminal atoms are arranged around the central atom, which is in turn determined by how the electron groups are arranged around the central atom. The electron groups on the terminal atoms do not affect this arrangement.

Cc 5.6 **(a)** HCN has two electron groups (the single bond and the triple bond) resulting in a linear geometry.

Cc 5.7 **(c)** Positions 1 and 4 would put the greatest distance between the lone pairs and minimize lone pair–lone pair repulsions.

Cc 5.8 **(d)** All electron groups on the central atom (or interior atoms, if there is more than one) determine the shape of a molecule according to VSEPR theory.