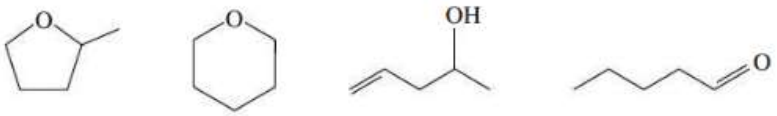
Assess

It may not be obvious that there is only one possibility for R. Try drawing structures of other ketones having the formula $C_6H_{12}O$ to convince yourself that there is only one possibility. Had we not been told the compound was acyclic, a unique identification would not have been possible.

PRACTICE EXAMPLE A: Compound A with the formula C_3H_8O is soluble in water and reacts with sodium metal, producing bubbles of gas. When compound A is treated with chromic acid (a mixture of $Na_2Cr_2O_7$ and H_2SO_4), compound B is formed. Compound B dissolves readily in $Na_2CO_3(aq)$ and reacts with ethanol, yielding compound C which has a fruity fragrance. Identify compounds A, B, and C.

PRACTICE EXAMPLE B: The following molecules all have the molecular formula $C_5H_{10}O$. You suspect that you have a sample of one of these compounds. What tests could you perform to ascertain which of these compounds you have?

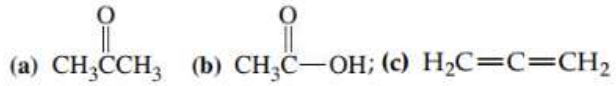


(a) (b) (c) (d)

Exercises

Organic Structures

1. Write structural formulas corresponding to the following condensed formulas.
   (a) $CH_3CH(CH_3)CH_2CBr_2CH_2CHClCH_3$
   (b) $CH_2{=}CHCH_2CHBrCH(CH_3)CH_3$
   (c) $CH_3CH_2CH_2C(CH_3)_2CH_3$
   (d) $CH_3C(CH_3)_2CH{=}C(CH_3)CH_2CH_3$
2. Draw a structural formula for each of the following compounds and provide the preferred IUPAC name.
   (a) 3-isopropyloctane; **(b)** 2-chloro-3-methylpentane; **(c)** 2-pentene; **(d)** dipropyl ether.
3. Supply a structural formula for each of the following compounds.
   (a) 1,3,5-trimethylbenzene; **(b)** *p*-nitrophenol; **(c)** 3-amino-2,5-dichlorobenzoic acid (a plant-growth regulator).
4. Write structural formulas corresponding to these condensed formulas.
   (a) $(CH_3)_3CCH_2CH(CH_3)CH_2CH_2CH_3$
   (b) $(CH_3)_2CHCH_2C(CH_3)_2CH_2Br$
   (c) $Cl_3CCH_2CH(CH_3)CH_2Cl$
5. Draw Lewis structures for the following simple organic molecules: **(a)** $CH_3CBr_2CH_2CH_3$; **(b)** $HOCH(CH_3)CH_2CH_3$; **(c)** CF_3COOH; **(d)** $CH_2BrC(O)CH_2CH_3$.
6. Draw Lewis structures of the following simple organic molecules: **(a)** CH_3CH_2COOH; **(b)** H_3CCN; **(c)** $CH_3CH_2NH_2$.
7. With appropriate sketches, represent chemical bonding in terms of the overlap of hybridized and unhybridized atomic orbitals in the following molecules.
   (a) C_4H_{10}; **(b)** $H_2C{=}CHCl$; **(c)** $CH_3C{\equiv}CH$
8. With appropriate sketches, represent chemical bonding in terms of the overlap of hybridized and unhybridized atomic orbitals in the following molecules.



(a) CH_3CCH_3 **(b)** $CH_3C{-}OH$; **(c)** $H_2C{=}C{=}CH_2$

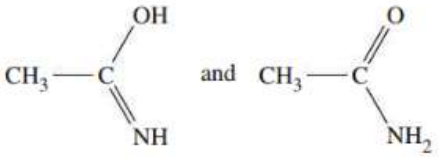
Isomers

9. What is the relationship, if any, between the molecules in each of the following pairs? The relationship may be any of identical structures, constitutional isomers, stereoisomers, or no relationship.

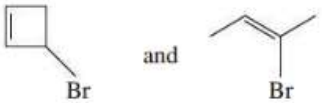
(a)

$CH_3CH_2CH_2Cl$ and $ClCH_2CH_2CH_3$

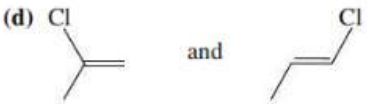
(b)



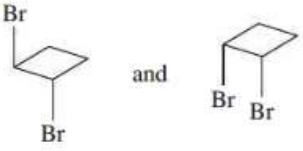
(c)



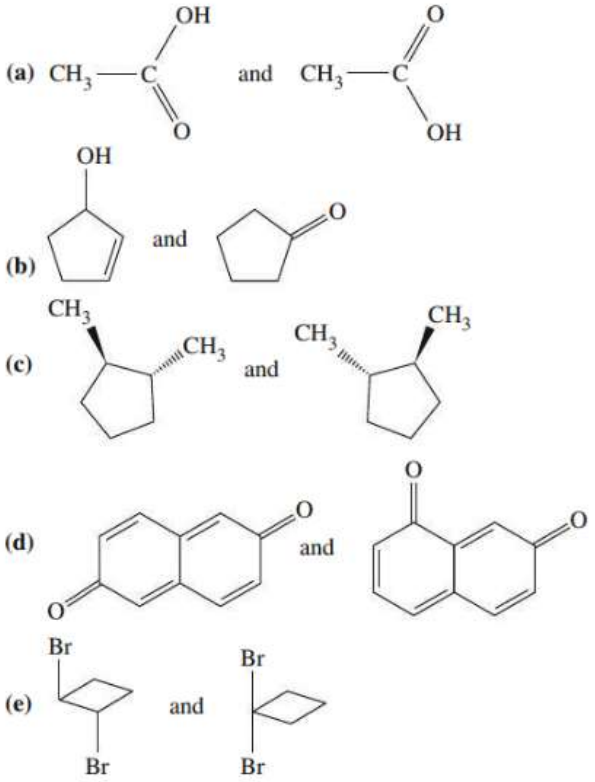
(d)



(e)



10. What is the relationship, if any, between the molecules in each of the following pairs? The relationship may be any of identical structures, constitutional isomers, stereoisomers, or no relationship.



11. Draw structural formulas for all isomers of pentanol, $C_5H_{11}OH$.

12. Draw and name all the isomers of **(a)** C_6H_{14}; **(b)** C_4H_8; **(c)** C_4H_6. [*Hint:* Do not forget double bonds, rings, and combinations of these.]

Functional Groups

17. Classify each compound by its functional group (i.e., alcohol, amine, etc.).

(a) $CH_3CHBrCH_2CH_3$
(b) $C_6H_5CH_2CHO$
(c) $CH_3COCH_2CH_3$
(d) $C_6H_4(OH)_2$

18. Classify each compound by its functional group (i.e., alcohol, amine, etc.).

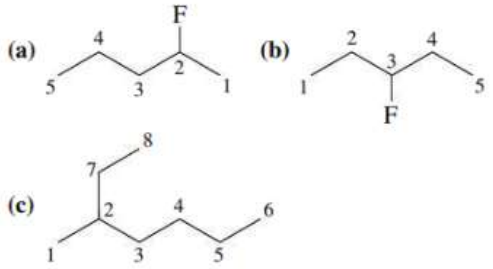
(a) $CH_3CH_2CH_2CH(OH)CH_3$
(b) $CH_3C(CH_3)_3CH_2COOH$
(c) $CH_3CH(CH_3)COOCH_2CH_3$
(d) $CH_3C(CH_3)_2NH_2$
(e) $CH_3CH_2CH_2CHO$

19. The functional groups in each of the following pairs have certain features in common, but what is the essential difference between them?

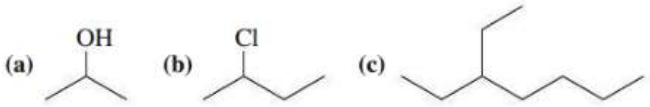
(a) carbonyl and carboxyl
(b) aldehyde and ketone
(c) acetic acid and acetyl group

20. By name or formula, give one example of each of the following types of compounds: **(a)** aromatic nitro compound; **(b)** aliphatic amine; **(c)** chlorophenol; **(d)** aliphatic diol; **(e)** unsaturated aliphatic alcohol; **(f)** alicyclic ketone; **(g)** halogenated alkane; **(h)** aromatic dicarboxylic acid.

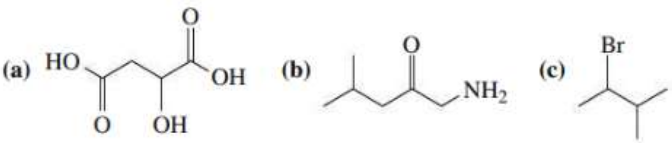
13. Identify the chiral carbon atoms, if any, in the following compounds.



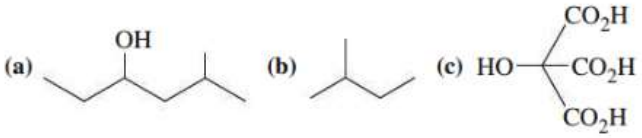
14. Identify the chiral carbon atoms, if any, in the following compounds.



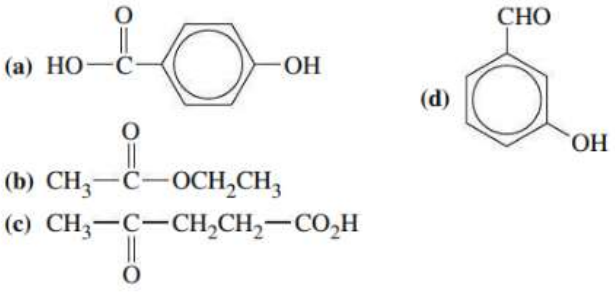
15. Identify the chiral carbon atoms, if any, in the following compounds:



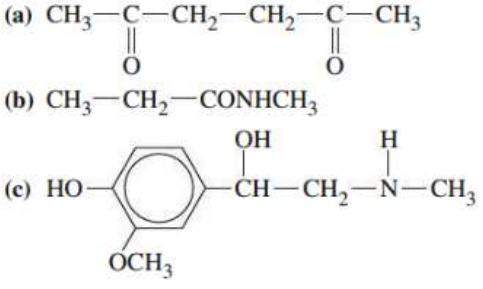
16. Identify the chiral carbon atoms, if any, in the following compounds.

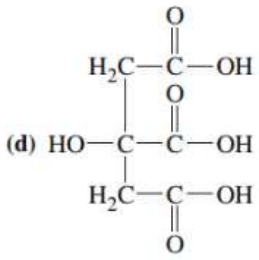


21. Identify and name the functional groups in each of the following.



22. Identify and name the functional groups in each of the following.

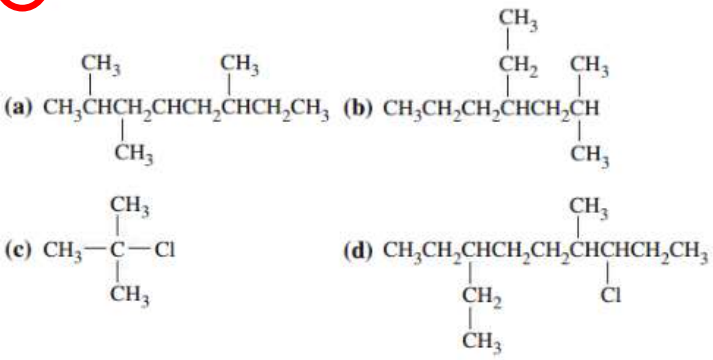




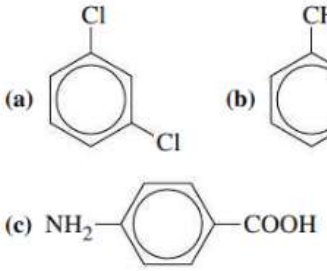
23. Give the isomers of $C_4H_{10}O$ that are ethers.
24. Give the isomers of $C_5H_{12}O$ that are ethers.
25. Give the isomers of the carboxylic acid with molecular formula $C_5H_{10}O_2$.
26. Give the isomers of the carboxylic acid with the molecular formula $C_4H_8O_2$.
27. Give the isomers of the esters having the molecular formula $C_5H_{10}O_2$.
28. Give the isomers of the esters having the molecular formula $C_4H_8O_2$.
29. Give the noncyclic isomers with molecular formula $C_4H_8O_2$ that contain more than one functional group.
30. Give the isomers with molecular formula $C_5H_{10}O_2$ that contain more than one functional group.

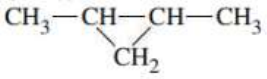
Nomenclature and Formulas

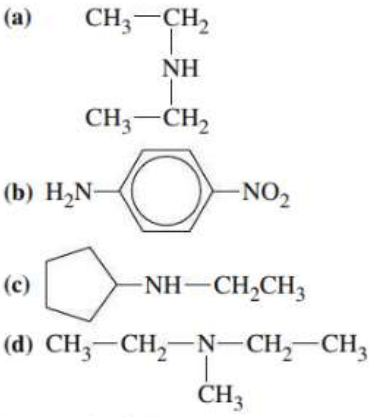
31. Give an acceptable name for each of the following.



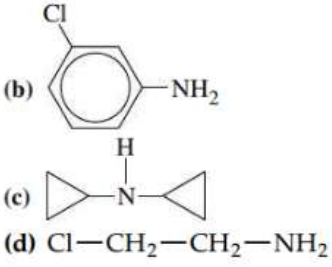
32. Give an acceptable name for each of the following.



33. Give an acceptable name for each of the following structures.
   (a) $CH_3CH_2C(CH_3)_3$
   (b) $(CH_3)_2C{=}CH_2$
   (c) 
   (d) $CH_3C{\equiv}CCH(CH_3)_2$
   (e) $CH_3CH(C_2H_5)CH(CH_3)CH_2CH_3$
   (f) $CH_3CH(CH_3)CH(CH_3)CCH_2CH_2CH{=}CH_2$
34. Draw a condensed structure to correspond to each of the following names.
   (a) methylbutane; **(b)** cyclohexene;
   (c) 2-methyl-3-hexyne; **(d)** 2-butanol;
   (e) ethyl isopropyl ether; **(f)** propanal
35. Does each of the following names convey sufficient information to suggest a specific structure? Explain.
   (a) pentene; **(b)** butanone; **(c)** butyl alcohol;
   (d) methylaniline; **(e)** methylcyclopentane;
   (f) dibromobenzene
36. Indicate why each of these names is incorrect, and give a correct name.
   (a) 3-pentene; **(b)** pentadiene; **(c)** 1-propanone;
   (d) bromopropane; **(e)** 2,6-dichlorobenzene;
   (f) 2-methyl-3-pentyne
37. Supply condensed structural formulas for the following substances.
   (a) 2,4,6-trinitrotoluene (TNT—an explosive)
   (b) methyl salicylate (oil of wintergreen)
   [*Hint:* Salicylic acid is *o*-hydroxybenzoic acid.]
   (c) 2-hydroxy-1,2,3-propanetricarboxylic acid (citric acid, $C_6H_8O_7$)
38. Supply condensed structural formulas for the following substances.
   (a) *o*-*tert*-butylphenol (an antioxidant in aviation gasoline)
   (b) 1-phenylpropan-2-amine (benzedrine—an amphetamine, ingredient in "pep pills")
   (c) 2-methylheptadecane (a sex pheromone of tiger moths—a chemical used for communication among members of the species) [*Hint:* Heptadeca means 17.]
39. Name the following amines.

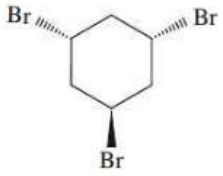


40. Name the following amines.
   (a) $CH_3{-}CH_2{-}NH_2$

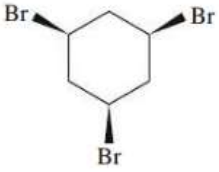


Alkanes and Cycloalkanes

41. Classify the carbon atoms in **(a)** methylbutane, and **(b)** 2,2-dimethylpropane as methyl, primary (1°), secondary (2°), tertiary (3°), or quaternary (4°).
42. Classify the carbon atoms in **(a)** 2,4-dimethylpentane, and **(b)** ethylcyclobutane as methyl, primary (1°), secondary (2°), tertiary (3°), or quaternary (4°).
43. Draw Newman projections for the staggered and eclipsed conformations of pentane for rotation about the C2—C3 bond. Which conformation is lowest in energy?
44. Draw Newman projections for the staggered and eclipsed conformations of 2-methylpentane for rotation about the C2—C3 bond. Which conformation is lowest in energy?
45. Draw the most stable conformation for the molecule below:



46. Draw the most stable conformation for the molecule below:

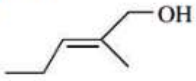


47. For each of the following substituted cyclohexanes, draw the two possible chair conformations, label each substituent as axial or equatorial, and identify the more stable conformer.
(a) cyclohexanol
(b) *trans*-3-methylcyclohexanol
48. For each of the following substituted cyclohexanes, draw the two possible chair conformations, label each substituent as axial or equatorial, and identify the more stable conformer.
(a) *cis*-1-isopropyl-3-methylcyclohexane
(b) *cis*-4-*tert*-butylcyclohexanol

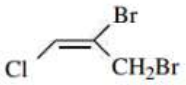
Alkenes

49. Why is it not necessary to refer to ethene and propene as eth-1-ene and prop-1-ene? Can the same be said for butene?
50. Alkenes (olefins) and cyclic alkanes (alicyclics) each have the generic formula C_nH_{2n}. In what important ways do these types of compounds differ structurally?
51. Assign a configuration (*E* or *Z*) to each of the following molecules.

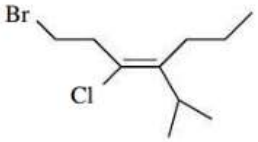
(a)



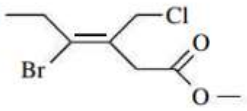
(b)



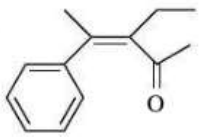
(c)



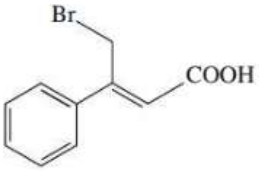
(d)



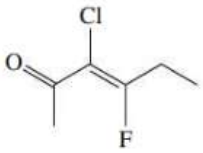
(e)



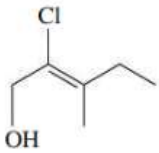
52. Assign a configuration (*E* or *Z*) to each of the following molecules.



(a)



(b)



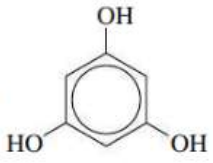
(c)

53. Draw the *E* and *Z* isomers of **(a)** 2-chlororbut-2-ene; **(b)** 3-methylpent-2-ene
54. Draw the *E* and *Z* isomers of **(a)** 3-methylhex-3-ene; **(b)** 3-fluoro-2-methylhex-3-ene

Aromatic Compounds

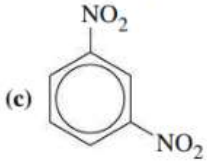
55. Supply a name or structural formula for each of the following.
(a) phenylacetylene
(b) *m*-dichlorobenzene

(c)



56. Supply a name or structural formula for each of the following.
(a) *p*-phenylphenol
(b) 3-hydroxy-4-isopropyltoluene (thymol—flavor constituent of the herb thyme)

(c)



Organic Stereochemistry

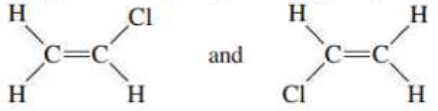
57. Draw suitable structural formulas to show that there are *four* constitutional isomers of $C_3H_6Cl_2$.

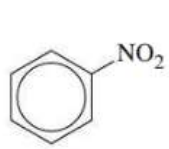
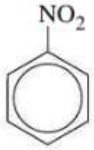
58. Which of the following pairs of molecules are constitutional isomers and which are not? Explain.

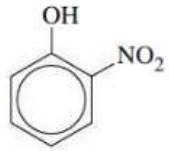
(a) $CH_3CH_2CH_2CH_3$ and $CH_3CH{=}CHCH_3$

(b) $CH_3(CH_2)_5CH(CH_3)_2$ and $CH_3(CH_2)_4CH(CH_3)CH_2CH_3$

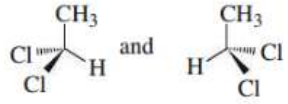
(c) $CH_3CHClCH_2CH_3$ and $CH_3CH_2CH_2CH_2CH_2Cl$

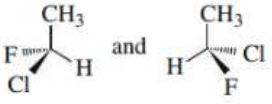
(d)  and

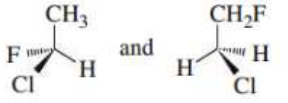
(e)  and 

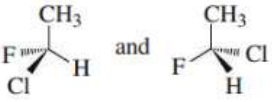
(f)  and 

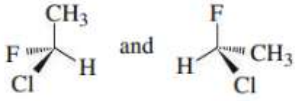
59. For each pair of structures shown below, indicate whether the two species are identical molecules, enantiomers, or isomers of some other sort.

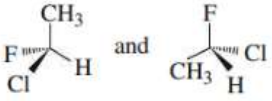
(a) 

(b) 

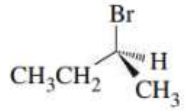
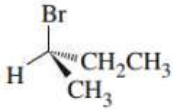
(c) 

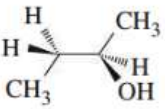
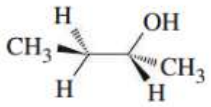
(d) 

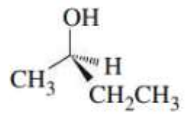
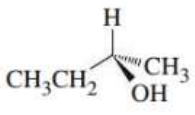
(e) 

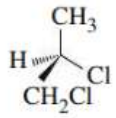
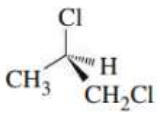
(f) 

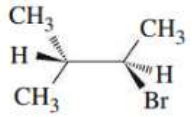
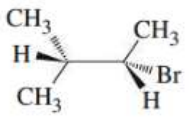
60. For each pair of structures shown below, indicate whether the two species are identical molecules, enantiomers, or isomers of some other sort.

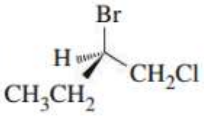
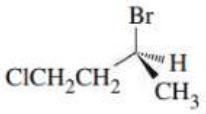
(a)  

(b)  

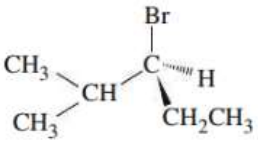
(c)  

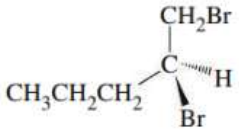
(d)  

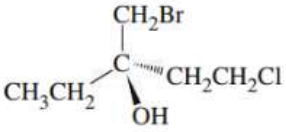
(e)  

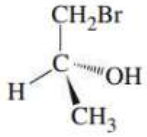
(f)  

61. Name the following molecules with the appropriate stereochemical designation.

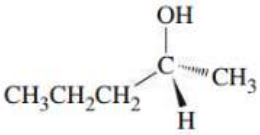
(a) 

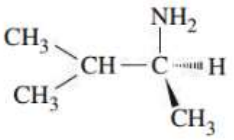
(b) 

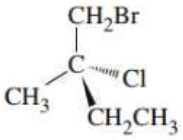
(c) 

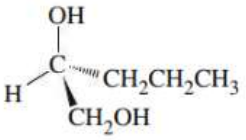
(d) 

62. Name the following molecules with the appropriate stereochemical designation.

(a) 

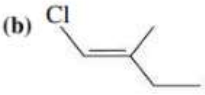
(b) 

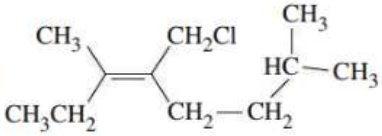
(c) 

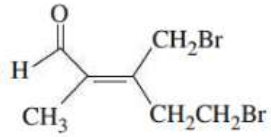
(d) 

63. Name the following molecules with the appropriate stereochemical designation.

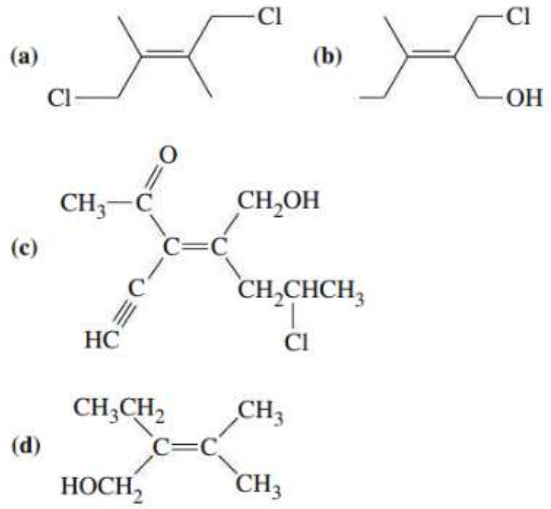
(a) 

(b) 

(c) 

(d) 

64. Name the following molecules with the appropriate stereochemical designation.



65. Draw the structure for each of the following.
(a) (*Z*)-1,3,5-tribromopent-2-ene
(b) (*E*)-1,2-dibromo-3-methylhex-2-ene
(c) (*S*)-1-bromo-1-chlorobutane
(d) (*R*)-1,3-dibromohexane
(e) (*S*)-1-chloropropan-2-ol

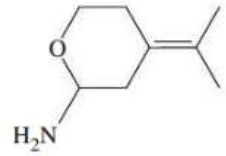
66. Draw the structure for each of the following.
(a) (*R*)-1-bromo-1-chloroethane
(b) (*E*)-2-bromopent-2-ene
(c) (*Z*))-1-chloro-3-ethylhept-3-ene
(d) (*R*)-2-hydroxypropanoic acid
(e) (*S*)-2-aminopropanoate anion

Structures and Properties of Organic Compounds

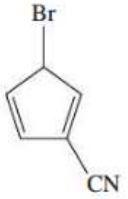
67. Consider the following molecular formulas. How many elements of unsaturation are there in each case? **(a)** $C_4H_{11}N$; **(b)** C_4H_6O; **(c)** $C_9H_{15}ClO$.

68. Consider the following molecular formulas. How many elements of unsaturation are there in each case? **(a)** C_5H_9NO **(b)** $C_5H_8O_3$; **(c)** C_5H_9ClO.

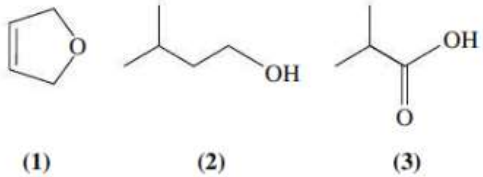
69. How many elements of unsaturation are there in the molecule below? What is the molecular formula?



70. How many elements of unsaturation are there in the molecule below? What is the molecular formula?



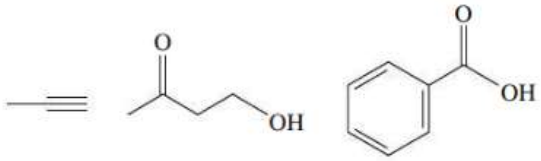
71. Match the following compounds with the chemical properties in the next column. Write a chemical equation for the reactions described in (a)–(d).



(1) **(2)** **(3)**

(a) is easily oxidized
(b) decolorizes bromine water
(c) generates bubbles of gas when treated with $Na_2CO_3(aq)$
(d) generates bubbles of gas when sodium metal is added

72. Match the following compounds with the chemical properties given below. Write a chemical equation for the reactions described in (a)–(d).



(1) **(2)** **(3)**

(a) forms an ester with ethanol
(b) absorbs H_2 in the presence of a metal catalyst
(c) neutralizes NaOH
(d) forms an ether when heated strongly with H_2SO_4

73. Draw as many structural isomers as you can for cyclic ethers (no —OH groups) having the formula C_4H_6O. Try to draw at least six. (There are more than six.)

74. Draw as many structural isomers as you can for cyclic alcohols having the formula C_4H_6O. Try to draw at least five. (There are more than five.)

Integrative and Advanced Exercises

75. Supply condensed or structural formulas for the following substances.
(a) cycloocta-1,5-diene (an intermediate in the manufacture of resins)
(b) 3,7,11-trimethyl-2,6,10-dodecatriene-1-ol (farnesol—odor of lily of the valley) [*Hint:* Dodeca means 12.]
(c) 2,6-dimethyl-5-hepten-1-al (used in the manufacture of perfume)

76. Draw structural formulas for all the isomers listed in Table 26.3, and show that, indeed, the substances with more compact structures have lower boiling points.

77. By drawing suitable structural formulas, establish that there are *17* isomers of $C_6H_{13}Cl$. [*Hint:* Refer to Example 26-1.]

78. The symbol:

is often used to represent benzene. It is also the structural formula of cyclohexatriene. Are benzene and cyclohexatriene the same substance? Explain.

79. Use the half-reaction method to balance the following redox equations.
(a) $C_6H_5NO_2 + Fe + H^+ \longrightarrow C_6H_5NH_3^+ + Fe^{3+} + H_2O$
(b) $C_6H_5CH_2OH + Cr_2O_7^{2-} + H^+ \longrightarrow C_6H_5CO_2H + Cr^{3+} + H_2O$
(c) $CH_3CH{=}CH_2 + MnO_4^- + H_2O \longrightarrow CH_3CHOHCH_2OH + MnO_2 + OH^-$

80. A 10.6 g sample of benzaldehyde was allowed to react with 5.9 g $KMnO_4$ in an excess of KOH(aq). After filtration of the $MnO_2(s)$ and acidification of the solution, 6.1 g of benzoic acid was isolated. What was the percent yield of the reaction? [*Hint:* Write half-equations for the oxidation and reduction half-reactions.]

81. Combustion of a 0.1908 g sample of a compound gave 0.2895 g CO_2 and 0.1192 g H_2O. Combustion of a second sample weighing 0.1825 g yielded 40.2 mL of $N_2(g)$, collected over 50% KOH(aq) (vapor pressure = 9 mmHg) at 25 °C and 735 mmHg barometric pressure. When 1.082 g of compound was dissolved in 26.00 g benzene (mp 5.50 °C, K_f = 5.12 °C mol kg^{-1}), the solution had a freezing point of 3.66 °C. What is the molecular formula of this compound?

82. Draw and name all derivatives of benzene having the formula **(a)** C_8H_{10}; **(b)** C_9H_{12}.

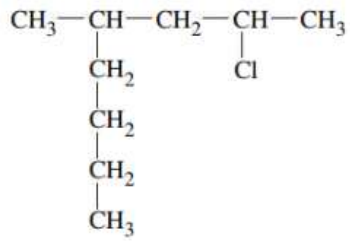
83. In the monochlorination of hydrocarbons, a hydrogen atom is replaced by a chlorine atom. How many different monochloro derivatives of 2-methylbutane are possible?

84. A particular colorless organic liquid is known to be one of the following compounds: butan-1-ol diethyl ether, methyl propyl ether, butyraldehyde, or propionic acid. Can you identify which it is, based on the following tests? If not, what additional test would you perform? (1) A 2.50 g sample dissolved in 100.0 g water has a freezing point of −0.7 °C. (2) An aqueous solution of the liquid does not change the color of blue litmus paper. (3) When alkaline $KMnO_4(aq)$ is added to the liquid and the mixture is heated, the purple color of the MnO_4^- disappears.

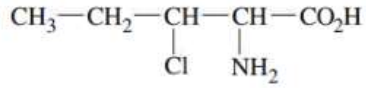
85. Write structural formulas for the following.
(a) 2,4-dimethylpenta-1,4-diene
(b) 2,3-dimethylpentane
(c) 1,2,4-tribromobenzene
(d) methyl ethanoate
(e) butanone

86. Give the systematic names, including any stereochemical designations, for each of the following.

(a)

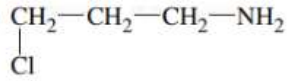


(b)

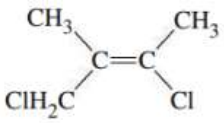


(c) $CH_3OCH_2CH_3$

(d)



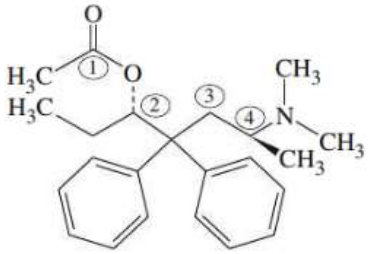
(e)



87. Write structural formulas for all the isomers of C_4H_7Cl. Indicate any enantiomers or diastereomers that occur.

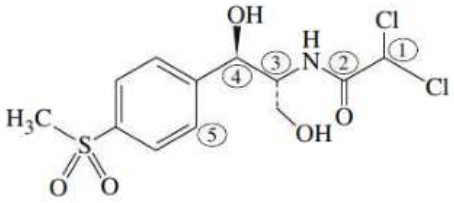
88. Compound A is an alcohol of formula $C_5H_{12}O$ that can be resolved into enantiomers.
(a) Draw *three* possible structures of compound A.
(b) Treatment of A with CrO_3/pyridine gives compound B, which also exhibits optical activity. What are the structural formulas of A and of B? Name and draw the enantiomers of A and B.

89. Levomethadyl acetate (shown below) is used in the treatment of narcotic addiction.



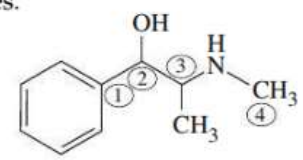
(a) Name the functional groups in levomethadyl acetate. **(b)** What is the hybridization of the numbered carbon atoms and the nitrogen atom? **(c)** Which, if any, of the numbered carbon atoms are chiral?

90. Thiamphenicol (shown below) is an antibacterial agent.



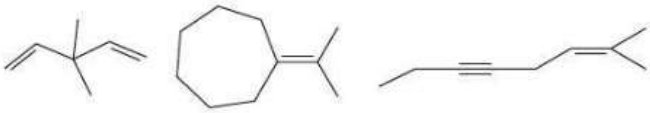
(a) Name the functional groups of thiamphenicol.
(b) What is the hybridization of the numbered carbon atoms and the nitrogen atom?
(c) Which, if any, of the numbered carbon atoms are chiral?

91. Ephedrine (shown below) is used as a decongestant in cold remedies.



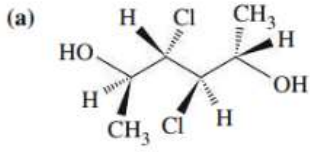
(a) Name the functional groups of ephedrine. **(b)** What is the hybridization of the numbered carbon atoms and the nitrogen atom? **(c)** Which, if any, of the numbered carbon atoms are chiral? **(d)** The pH of a solution of 1 g of ephedrine in 200 g of water is 10.8. What is the pK_b of ephedrine?

92. For each of the following molecules, determine the hybridization of each carbon atom, the total number of carbon–carbon σ bonds and the total number of carbon–carbon π bonds. Also, among the sp^3-hybridized carbon atoms, which ones are primary (1°), secondary (2°), tertiary (3°), or quaternary (4°)?

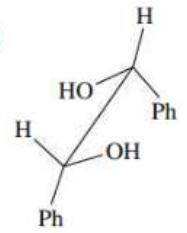


(a) **(b)** **(c)**

93. Determine the configuration, *R* or *S*, of each chiral carbon atom in the molecules that follow. (Ph represents a phenyl group.)



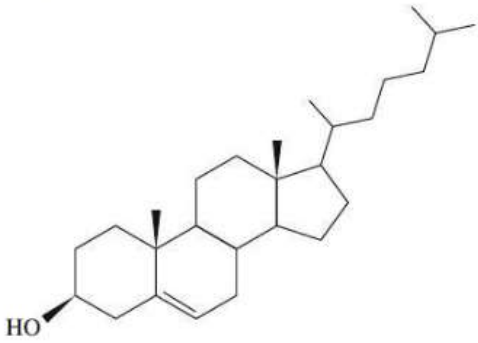
(a)



(b)

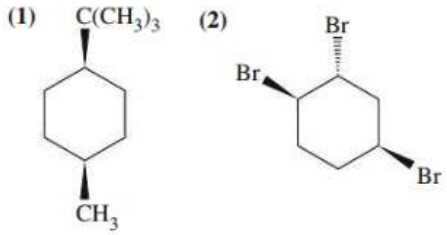
94. Among all ethers with the formula C_4H_6O, draw structures for
(a) two ethers with two sp^2 and two sp^3 carbon atoms
(b) an ether with four sp^2 carbon atoms
(c) an ether with two sp and two sp^3 carbon atoms

95. A structural formula for cholesterol is shown below. How many chiral carbon atoms are there in the cholesterol molecule? What is the configuration, *R* or *S*, of the carbon atom bonded to the —OH group? What is the configuration, *E* or *Z*, of the double bond?



Cholesterol

96. For each of the following molecules **(a)** draw the two chair conformations and specify which conformation is more stable; **(b)** determine the number of chiral carbon atoms and for each chiral carbon, determine its configuration (*R* or *S*).



(1) **(2)**

Feature Problem

97. Organic chemists use a variety of methods to help them identify the functional groups in a molecule. In this chapter, we mentioned a few simple chemical ways to test for alkenes, alcohols, carboxylic acids, and so on. Such tests are quick and easy, but today organic chemists rely heavily on instrumental techniques. *Infrared (IR) spectroscopy* is an instrumental technique for identifying functional groups in a molecule. When infrared radiation is absorbed by a molecule, it causes atoms in bonds to vibrate back and forth with increased amplitude. We saw (in Chapter 8) that the energies of electrons in atoms are quantized and so too are the vibrations of atoms in molecules. Because each functional group has a particular grouping of atoms, there is a characteristic infrared absorption associated with each type of functional group. Some characteristic infrared absorptions are summarized in the following table. Infrared absorptions of molecules are identified by specifying the *wavenumber* of the light that is absorbed. The wavenumber is simply the reciprocal of wavelength: wavenumber $= 1/\lambda = \nu/c$. (The definitions of λ, ν, and c were given in Chapter 8.) The SI unit

for wavenumber is m^{-1} but it is often given in units of cm^{-1}. The wavenumber represents the number of cycles of the wave in each meter or centimeter along the light beam.

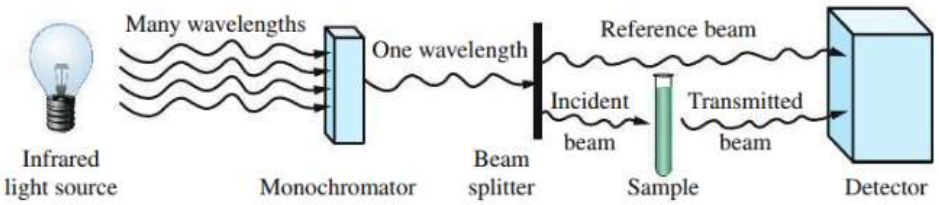
The data in the table indicate that molecules containing the carbonyl group (C═O) absorb light with wavenumbers between 1680 and 1750 cm^{-1}. Molecules containing a carbon–carbon triple bond (C≡C) absorb light with wavenumbers between 2100 and 2200 cm^{-1}. To identify the functional groups present in a molecule, the *infrared spectrum* of the molecule is obtained by using an instrument called an *infrared spectrometer*. A schematic diagram of an infrared spectrometer is shown below.

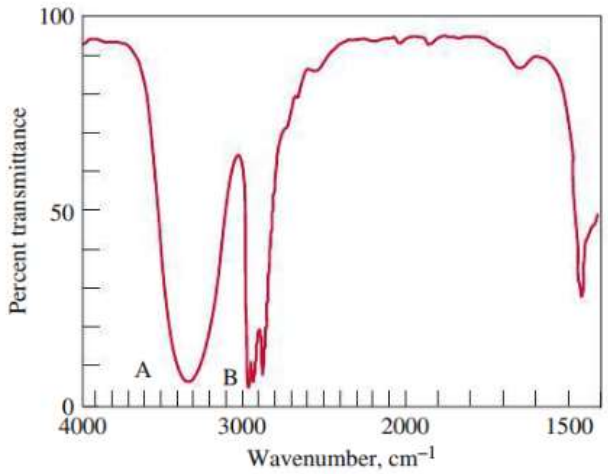
The light from the infrared light source is directed through a monochromator, which can be set to select a specific wavelength of light. The light then passes through a beam splitter, which splits the light into two separate beams, a reference beam and an incident beam. If the wavenumber of the incident beam matches one of the characteristic absorptions of the molecule, the sample absorbs the light, producing molecules that vibrate with greater energy. Because light has been absorbed by the sample, the intensity of the transmitted beam is less than that of the reference beam. The decrease in intensity is detected by the detector. By varying the wavenumber of light that reaches the sample and monitoring the percentage of light that is transmitted, an infrared spectrum is obtained (see graphs). An infrared spectrum is a plot of percent transmittance versus wavenumber. One hundred percent transmittance means none of the incident light was absorbed and 0% transmittance means all of the incident light was absorbed.

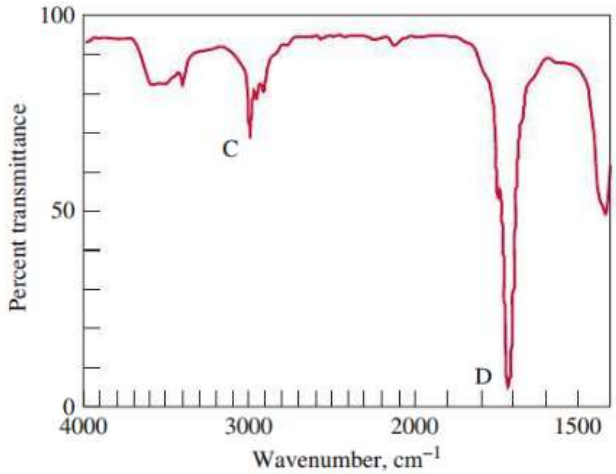
Type of bond	Wavenumber, cm^{-1}
Single bonds	
—C—H	2850–3300
=C—H	3000–3100
≡C—H	≈3300
N—H	3300–3500
O—H	3200–3600
Double bonds	
C═C	1620–1680
C═N	1500–1650
C═O	1680–1750
Triple bonds	
C≡C	2100–2200
C≡N	2200–2300

(a) The infrared absorptions given in the table above range from 1500 cm^{-1} to 3600 cm^{-1}. Calculate the corresponding ranges of wavelength and frequency to verify that these absorptions correspond to the infrared region of the electromagnetic spectrum. (See Figure 8-3.)
(b) Identify the bonds responsible for the absorptions labeled A, B, C, and D in the two infrared spectra shown here. One spectrum is for acetone and the other is for 1-propanol, both of which are colorless liquids. Which of the two spectra is that of acetone?
(c) An isomer of acetone exhibits a strong IR absorption at 1645 cm^{-1} and also absorbs strongly from 2860 through 3600 cm^{-1}. The compound decolorizes bromine water, $Br_2(aq)$, and produces bubbles of gas when sodium metal is added to it. What is the structure of this compound?

Infrared spectrometer







Self-Assessment Exercises

98. In your own words, define the following terms or symbols:
(a) *tert*-
(b) R—
(c) 
(d) carbonyl group
(e) primary amine

99. Explain the important distinctions between each pair of terms: **(a)** alkane and alkene; **(b)** aliphatic and aromatic compound; **(c)** alcohol and phenol; **(d)** ether and ester; **(e)** amine and ammonia.

100. Describe the characteristics of each of the following types of isomers: **(a)** constitutional; **(b)** stereoisomer; **(c)** cis; **(d)** ortho.

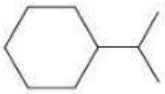
101. The compound isoheptane is best represented by the formula **(a)** C_7H_{14}; **(b)** $CH_3(CH_2)_5CH_3$; **(c)** $(CH_3)_2CH(CH_2)_3CH_3$; **(d)** $C_6H_{11}CH_3$.

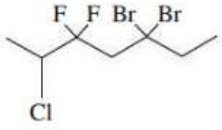
102. A compound with the same hydrogen-to-carbon ratio as cyclobutane is **(a)** C_4H_{10}; **(b)** $CH_3CH{=}CHCH_3$; **(c)** $CH_3C{\equiv}CCH_3$; **(d)** C_6H_6.

103. Three isomers exist of the hydrocarbon **(a)** C_3H_8; **(b)** C_4H_8; **(c)** C_4H_{10}; **(d)** C_6H_6; **(e)** C_5H_{12}.

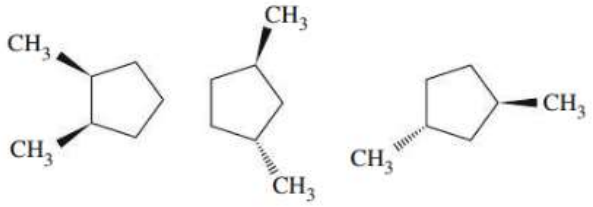
104. Give names for the following molecules.

(a) $(CH_3)_2CBrCH_2CHClCH_2CH(CH_3)_2$

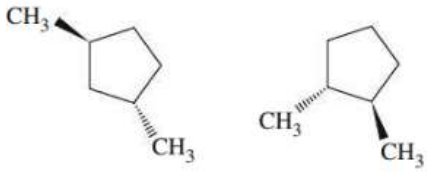
(b) 

(c) 

105. Assign configurations, *R* or *S*, to the chiral carbons in the molecules below. Then identify **(a)** any two identical structures; **(b)** any two constitutional isomers; **(c)** any two diastereomers; **(d)** a pair of enantiomers.

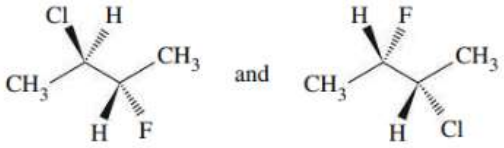


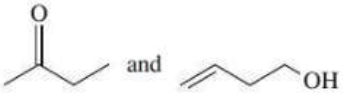
(1) **(2)** **(3)**

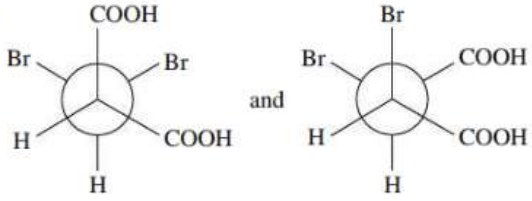


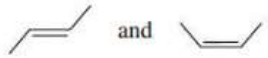
(4) **(5)**

106. Consider the following pairs of structures. In each case, are the structures different conformers or are they isomers? If they are isomers, then state whether they are constitutional isomers, diastereomers, or enantiomers.

(a) 

(b) 

(c) 

(d) 

107. Draw a Newman projection for the conformation of lowest energy for viewing 2-methylhexane along the C2—C3 bond.

108. To prepare methyl ethyl ketone, one should oxidize **(a)** propan-2-ol; **(a)** butan-1-ol; **(c)** butan-2-ol; **(d)** *tert*-butyl alcohol.

109. Which hydrocarbon has the greater number of isomers, C_4H_8 or C_4H_{10}? Explain your choice.

110. For each of the following pairs, indicate which substance has
(a) the higher boiling point, C_6H_{12} or C_2H_4
(b) the greater solubility in water, C_3H_7OH or $C_7H_{15}OH$
(c) the greater acidity in aqueous solution, C_6H_5CHO or C_6H_5COOH

111. Draw the structures of
(a) (*E*)-3-benzyl-2,5-dichloro-4-methylhex-3-ene
(b) 1-nitro-4-vinylbenzene [*Hint:* The vinyl group is $H_2C{=}CH^-$.]
(c) *trans*-1-(4-bromophenyl)-2-methylcyclohexane