Pearson

Exercises

Review Questions

1. What kinds of molecules often trigger our sense of smell?
2. What is organic chemistry?
3. What is unique about carbon and carbon-based compounds? Why did life evolve around carbon?
4. Why does carbon form such a large diversity of compounds?
5. Why does silicon exhibit less diversity of compounds than carbon does?
6. Describe the geometry and hybridization about a carbon atom that forms the following:
a. four single bonds.
b. two single bonds and one double bond.
c. one single bond and one triple bond.
7. What are hydrocarbons? What are their main uses?
8. What are the main classifications of hydrocarbons? What are their generic molecular formulas?
9. Explain the differences between a structural formula, a condensed structural formula, a carbon skeleton formula, a ball-and-stick model, and a space-filling model.
10. What are structural isomers? How do the properties of structural isomers differ from one another?
11. What are optical isomers? How do the properties of optical isomers differ from one another?
12. Define each term related to optical isomerism: enantiomers, chiral, dextrorotatory, levorotatory, racemic mixture.
13. What is the difference between saturated and unsaturated hydrocarbons?
14. What are the key differences in the way that alkanes, alkenes, and alkynes are named?
15. Explain geometric isomerism in alkenes. How do the properties of geometric isomers differ from one another?
16. Describe and provide an example of a hydrocarbon combustion reaction.
17. What kinds of reactions are common to alkanes? List an example of each.
18. Describe each kind of reaction.
a. substitution reaction
b. addition reaction
c. elimination reaction
19. What kinds of reactions are common to alkenes? List an example of each.
20. Explain Markovnikov's rule and give an example of a reaction to which it applies.
21. What is the structure of benzene? What are the different ways in which this structure is represented?
22. What kinds of reactions are common to aromatic compounds? Provide an example of each.
23. What is a functional group? List some examples.
24. What is the generic structure of alcohols? Write the structures of two specific alcohols.
25. Explain oxidation and reduction with respect to organic compounds.
26. Which kinds of reactions are common to alcohols? Provide an example of each.
27. What are the generic structures for aldehydes and ketones? Write a structure for a specific aldehyde and ketone.
28. Which kinds of reactions are common to aldehydes and ketones? List an example of each.
29. What are the generic structures for carboxylic acids and esters? Write a structure for a specific carboxylic acid and ester.
30. Which kinds of reactions are common to carboxylic acids and esters? Provide an example of each.
31. What is the generic structure of ethers? Write the structures of two specific ethers.
32. What is the generic structure of amines? Write the structures of two specific amines.

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 more loosely. Because of their nature, Challenge Problems and Conceptual Problems are unpaired.

Hydrocarbons

33. Based on the molecular formula, determine whether each compound is an alkane, alkene, or alkyne. (Assume that the hydrocarbons are noncyclic and there is no more than one multiple bond.)

a. C_5H_{12}

b. C_3H_6

c. C_7H_{12}

d. $C_{11}H_{22}$

34. Based on the molecular formula, determine whether each compound is an alkane, alkene, or alkyne. (Assume that the hydrocarbons are noncyclic and there is no more than one multiple bond.)

a. C_8H_{16}

b. C_4H_6

c. C_7H_{16}

d. C_2H_2

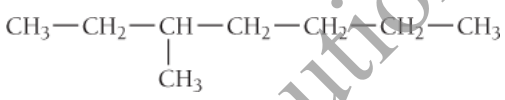
35. Write structural formulas for each of the nine structural isomers of heptane.

36. Write structural formulas for any 6 of the 18 structural isomers of octane.

37. Determine whether each compound exhibits optical isomerism.

a. CCl_4

b.



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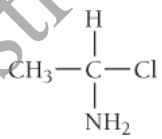


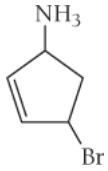
d. $CH_3CHClCH_3$

38. Determine whether each compound exhibits optical isomerism.

a. $CH_3CH_2CHClCH_3$

b. $CH_3CCl_2CH_3$

c.



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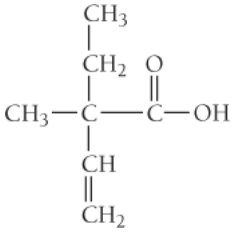
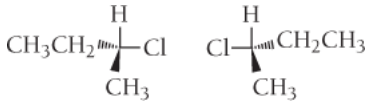


39. Determine whether the molecules in each pair are the same or enantiomers.

a.



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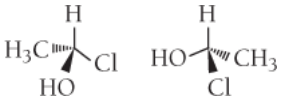

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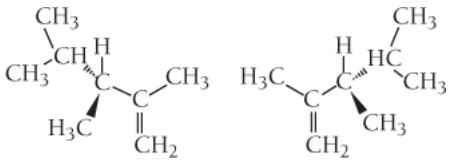
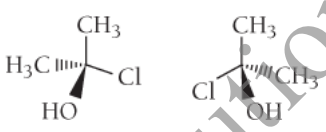


40. Determine whether the molecules in each pair are the same or enantiomers.

a.



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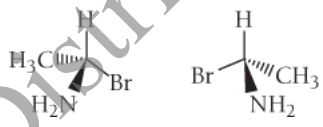

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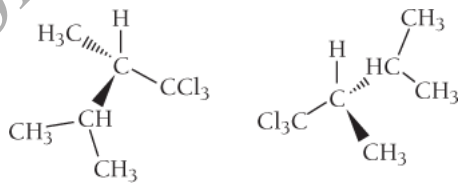
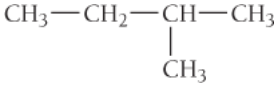


Alkanes

41. Name each alkane.

a. $CH_3–CH_2–CH_2 – CH_2–CH_3$

b.



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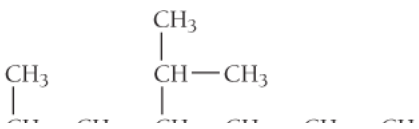

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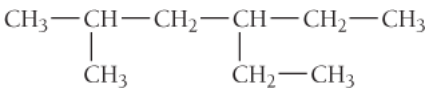
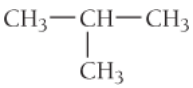


42. Name each alkane

a.



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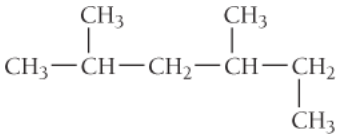

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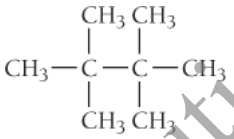

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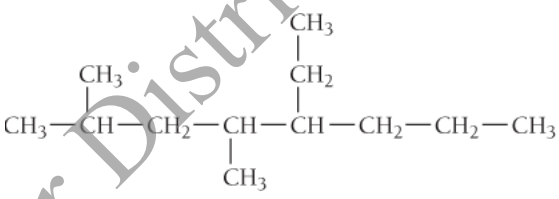


43. Draw a structure for each alkane.

a. 3-ethylhexane

b. 3-ethyl-3-methylpentane

c. 2,3-dimethylbutane

d. 4,7-diethyl-2,2-dimethylnonane

44. Draw a structure for each alkane.

a. 2,2-dimethylpentane

b. 3-isopropylheptane

c. 4-ethyl-2,2-dimethylhexane

d. 4,4-diethyloctane

45. Complete and balance each hydrocarbon combustion reaction.

a. $CH_3CH_2CH_3 + O_2 \rightarrow$

b. $CH_3CH_2CH{=}CH_2 + O_2 \rightarrow$

c. $CH \equiv CH + O_2 \rightarrow$

46. Complete and balance each hydrocarbon combustion reaction.

a. $CH_3CH_2CH_2CH_3 + O_2 \rightarrow$

b. $CH_2{=}CHCH_3 + O_2 \rightarrow$

c. $CH \equiv CCH_2CH_3 + O_2 \rightarrow$

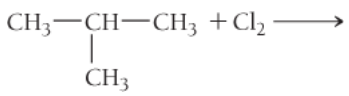
47. List all the possible products for each alkane substitution reaction. (Assume monosubstitution.)

a. $CH_3CH_3 + Br_2 \rightarrow$

b. $CH_3CH_2CH_3 + Cl_2 \rightarrow$

c. $CH_2Cl_2 + Br_2 \rightarrow$

d.



48. List all the possible products for each alkane substitution reaction. (Assume monosubstitution.)

a. $CH_4 + Cl_2 \rightarrow$

b. $CH_3CH_2Br + Br_2 \rightarrow$

c. $CH_3CH_2CH_2CH_3 + Cl_2 \rightarrow$

d. $CH_3CHBr_2 + Br_2 \rightarrow$

Alkenes and Alkynes

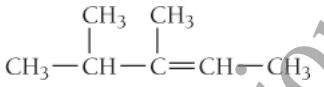
49. Write structural formulas for each of the possible isomers of *n*-hexene that are formed by moving the position of the double bond.

50. Write structural formulas for each of the possible isomers of *n*-pentyne that are formed by moving the position of the triple bond.

51. Name each alkene.

a. CH_2=CH–CH_2–CH_3

b.



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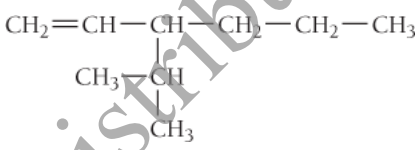

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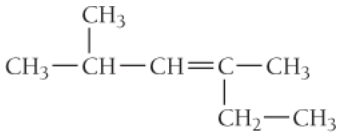
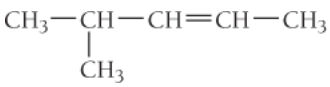


52. Name each alkene.

a. CH_3–CH_2–CH=CH–CH_2–CH_3

b.



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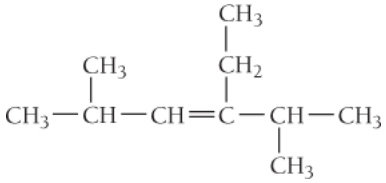

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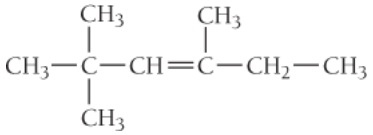
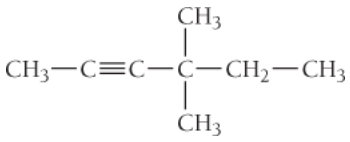


53. Name each alkyne.

a. $CH_3–C \equiv C–CH_3$

b.



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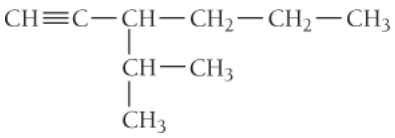

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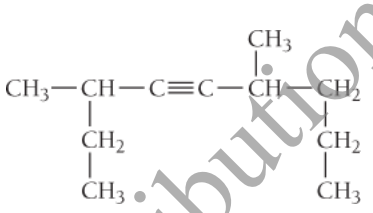
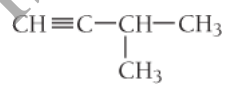
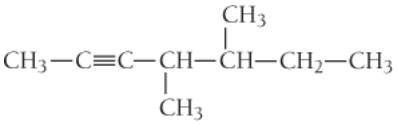


54. Name each alkyne.

a.



b.



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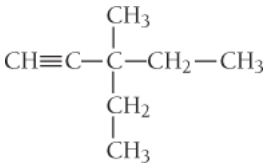

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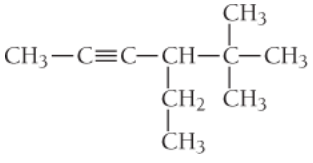


55. Draw the correct structure for each compound.

a. 4-octyne

b. 3-nonene

c. 3,3-dimethyl-1-pentyne

d. 5-ethyl-3,6-dimethyl-2-heptene

56. Draw the correct structure for each compound.

a. 2-hexene

b. 1-heptyne

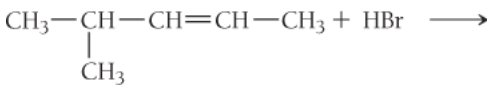
c. 4,4-dimethyl-2-hexene

d. 3-ethyl-4-methyl-2-pentene

57. List the products of each alkene addition reaction.

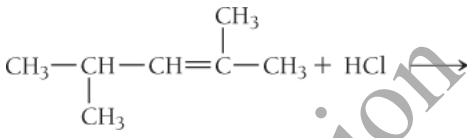
a. $CH_3–CH=CH–CH_3 + Cl_2 \rightarrow$

b.



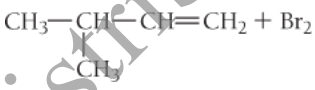
c. $CH_3–CH_2–CH=CH–CH_3 + Br_2 \rightarrow$

d.



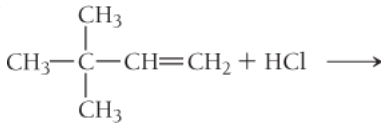
58. What are the products of each alkene addition reaction?

a.



b. $CH_2=CH–CH_3 + Cl_2 \rightarrow$

c.



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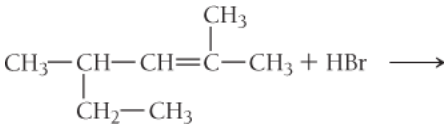
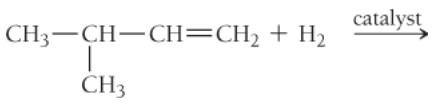


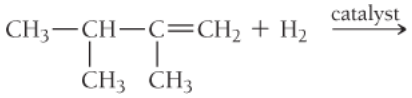
59. Complete each hydrogenation reaction.

a. $CH_2=CH–CH_3 + H_2 \xrightarrow{\text{catalyst}}$

b.



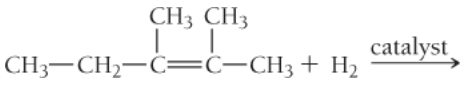
c.



60. Complete each hydrogenation reaction.

a. $CH_3–CH_2–CH{=}CH_2 + H_2 \xrightarrow{\text{catalyst}}$

b.



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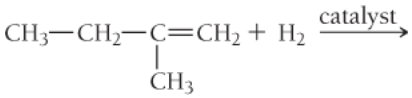
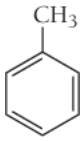


Aromatic Hydrocarbons

61. Name each monosubstituted benzene.

a.



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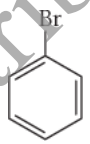

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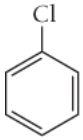
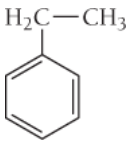
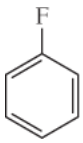


62. Name each monosubstituted benzene.

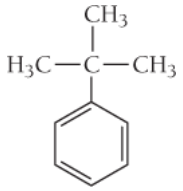
a.



b.

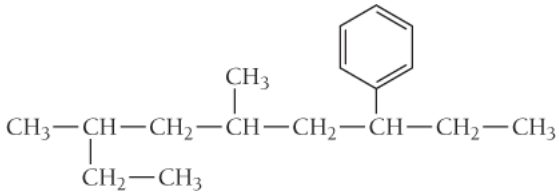


c.

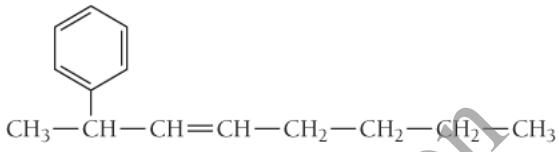


63. Name each compound in which the benzene ring is best treated as a substituent.

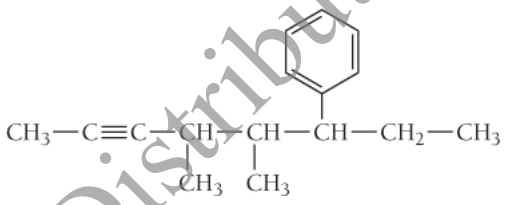
a.



b.

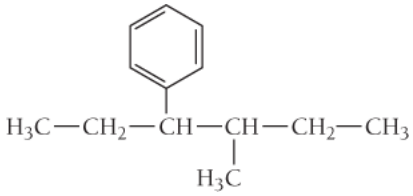


c.

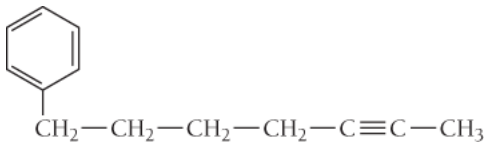


64. Name each compound in which the benzene ring is best treated as a substituent.

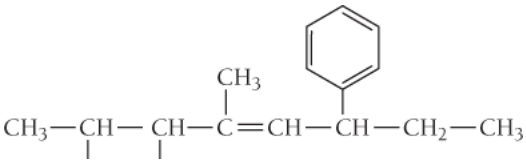
a.

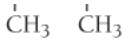


b.



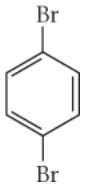
c.



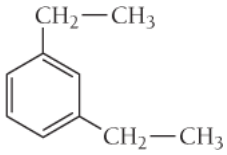


65. Name each disubstituted benzene.

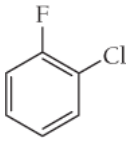
a.



b.

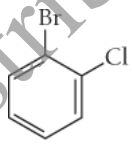


c.

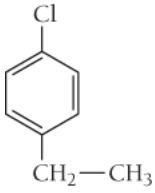


66. Name each disubstituted benzene.

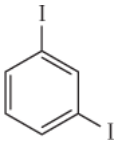
a.



b.



c.



67. Draw the structure for each compound.

a. isopropylbenzene

b. *meta*-dibromobenzene

c. 1-chloro-4-methylbenzene

68. Draw the structure for each compound.

a. ethylbenzene

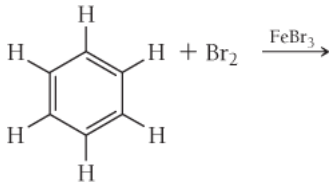
b. 1-iodo-2-methylbenzene

b. 1-iodo-2-methylbenzene

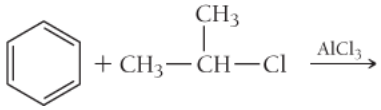
c. *para*-diethylbenzene

69. What are the products of each aromatic substitution reaction?

a.

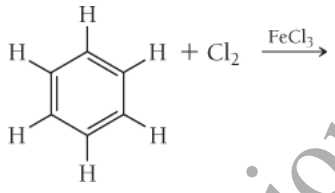


b.

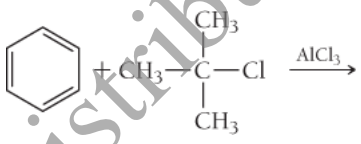


70. What are the products of each aromatic substitution reaction?

a.



b.

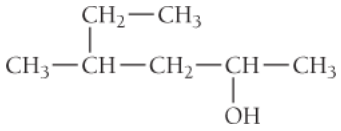


Alcohols

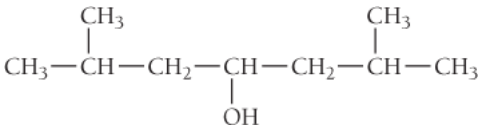
71. Name each alcohol.

a. $CH_3–CH_2–CH_2–OH$

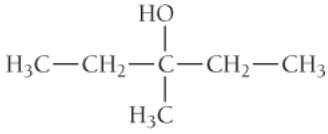
b.



c.



d.



72. Draw the structure for each alcohol.

a. 2-butanol

b. 2-methyl-1-propanol

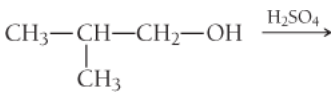
c. 3-ethyl-1-hexanol

d. 2-methyl-3-pentanol

73. List the products of each alcohol reaction.

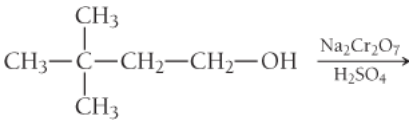
a. $CH_3–CH_2–CH_2–OH + HBr \rightarrow$

b.



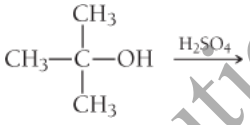
c. $CH_3–CH_2–OH + Na \rightarrow$

d.

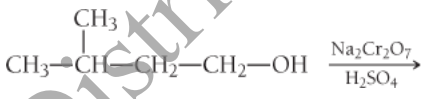


74. List the products of each alcohol reaction.

a.

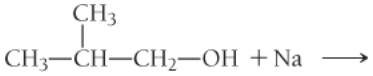


b.



c. $CH_3–CH_2–OH + HCl \rightarrow$

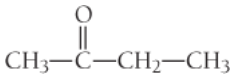
d.



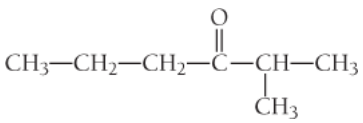
Aldehydes and Ketones

75. Name each aldehyde or ketone.

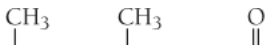
a.

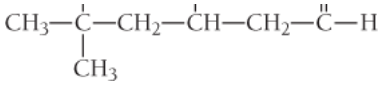


b.

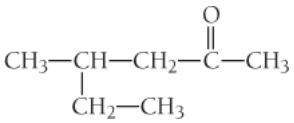


c.





d.



76. Draw the structure of each aldehyde or ketone.

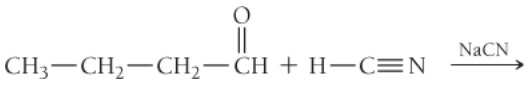
a. hexanal

b. 2-pentanone

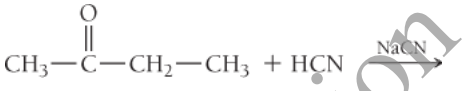
c. 2-methylbutanal

d. 4-heptanone

77. Determine the product of the addition reaction.



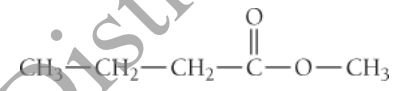
78. Determine the product of the addition reaction.



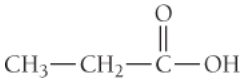
Carboxylic Acids and Esters

79. Name each carboxylic acid or ester.

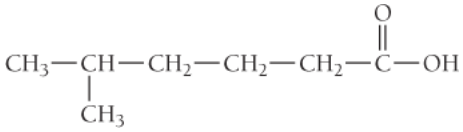
a.



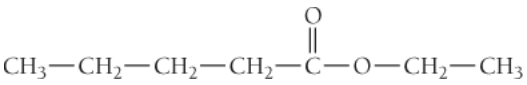
b.



c.



d.



80. Draw the structure of each carboxylic acid or ester.

a. pentanoic acid

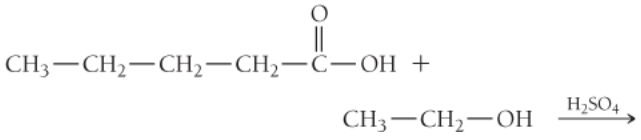
b. methyl hexanoate

c. 3-ethylheptanoic acid

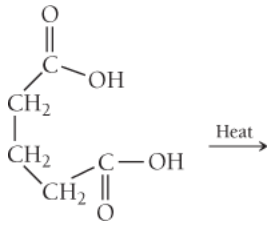
d. butyl ethanoate

81. Determine the products of each carboxylic acid reaction.

a.

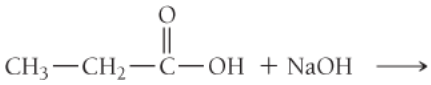


b.

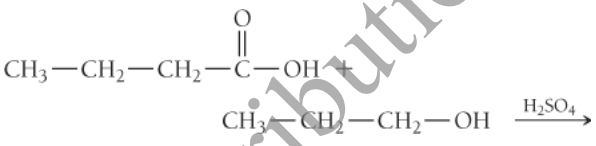


82. Determine the products of each carboxylic acid reaction.

a.



b.



Ethers

83. Name each ether.

a. $CH_3–CH_2–CH_2–O–CH_2–CH_3$

b. $CH_3–CH_2–CH_2–CH_2–CH_2–O–CH_2–CH_3$

c. $CH_3–CH_2–CH_2–O–CH_2–CH_2–CH_3$

d. $CH_3–CH_2–O–CH_2–CH_2–CH_2–CH_3$

84. Draw the structure for each ether.

a. ethyl propyl ether

b. dibutyl ether

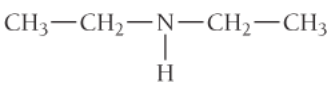
c. methyl hexyl ether

d. dipentyl ether

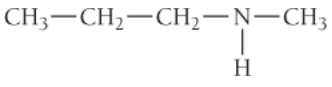
Amines

85. Name each amine.

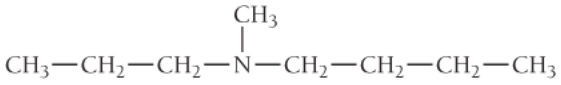
a.



b.



c.



86. Draw the structure for each amine.

a. isopropylamine

b. triethylamine

c. butylethylamine

87. Classify each amine reaction as acid–base or condensation and list its products.

a. $CH_3NHCH_3 + HCl \rightarrow$

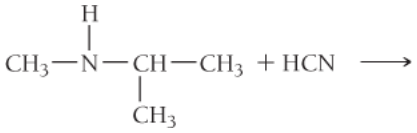
b. $CH_3CH_2NH_2 + CH_3CH_2COOH \rightarrow$

c. $CH_3NH_2 + H_2SO_4 \rightarrow$

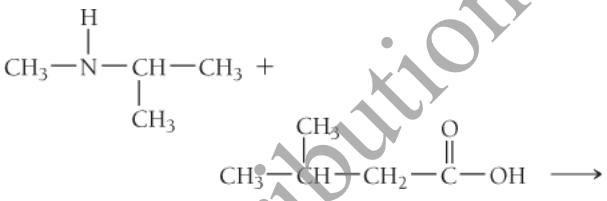
88. List the products of each amine reaction.

a. $N(CH_2CH_3)_3 + HNO_3 \rightarrow$

b.



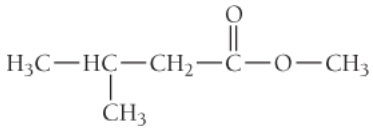
c.



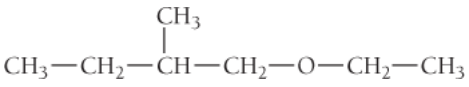
Cumulative Problems

89. Identify each organic compound as an alkane, alkene, alkyne, aromatic hydrocarbon, alcohol, ether, aldehyde, ketone, carboxylic acid, ester, or amine, and provide a name for the compound.

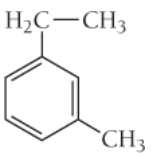
a.



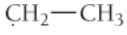
b.

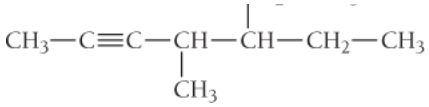


c.

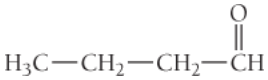


d.

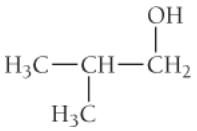




e.

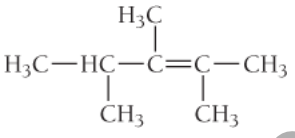


f.



90. Identify each organic compound as an alkane, alkene, alkyne, aromatic hydrocarbon, alcohol, ether, aldehyde, ketone, carboxylic acid, ester, or amine, and provide a name for the compound.

a.



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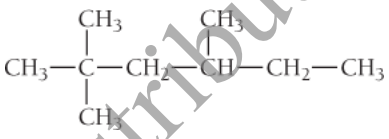

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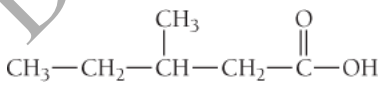

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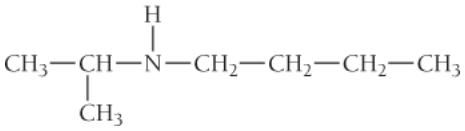
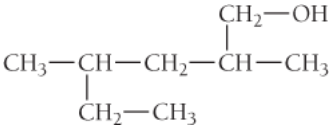
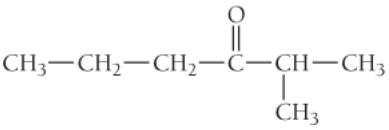


e.

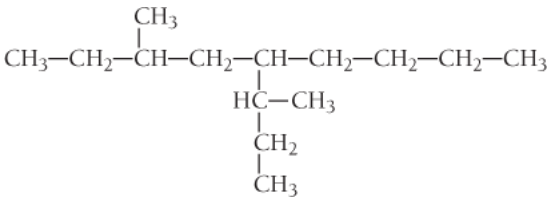


f.



91. Name each compound.

a.



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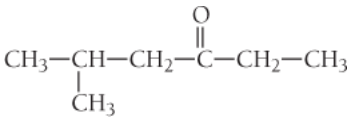

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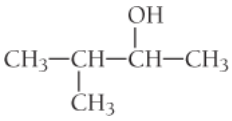

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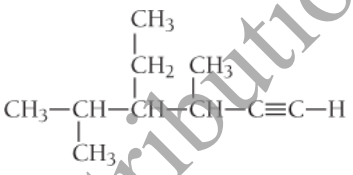
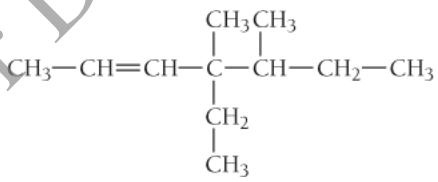


92. Name each compound.

a.



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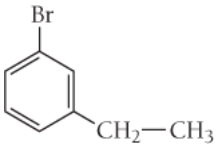

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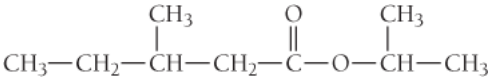
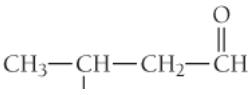
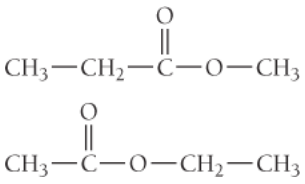


d.

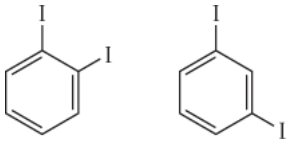


93. Determine whether each pair of structures are isomers or the same molecule drawn in two different ways.

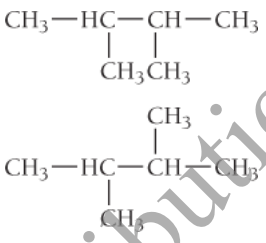
a.



b.

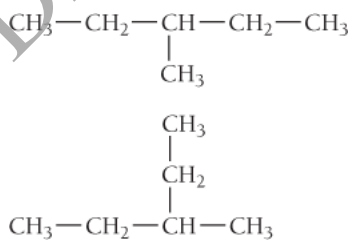


c.



94. Determine whether each pair of structures are isomers or the same molecule drawn two different ways.

a.



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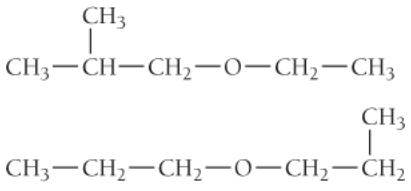
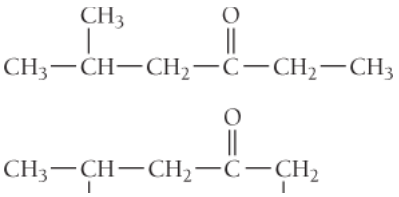


c.



95. What minimum amount of hydrogen gas, in grams, is required to completely hydrogenate 15.5 kg of 2-butene?

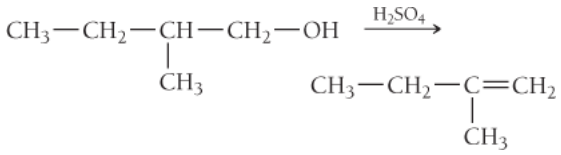
96. How many kilograms of CO_2 does the complete combustion of 3.8 kg of *n*-octane produce?

97. Classify each organic reaction as combustion, alkane substitution, alkene addition or hydrogenation, aromatic substitution, or alcohol substitution, elimination, or oxidation.

a. $2\ CH_3CH{=}CH_2 + 9\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

b. $CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CH_2CH_2Cl + HCl$

c.



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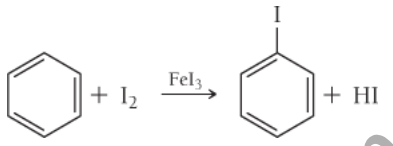
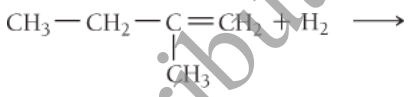


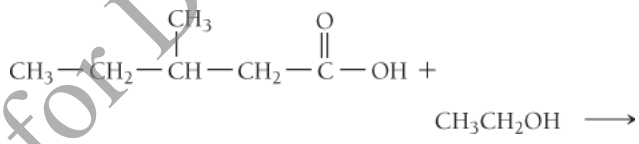
98. Determine the products of each reaction.

a.

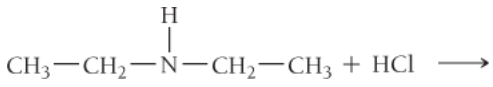


b. $CH_3{-}CH_2{-}CH_2{-}CH_2{-}OH + HCl \rightarrow$

c.



d.



99. Draw the structure that corresponds to each name and indicate which structures can exist as stereoisomers.

a. 3-methyl-1-pentene

b. 3,5-dimethyl-2-hexene

c. 3-propyl-2-hexene

100. Identify the two compounds that display stereoisomerism and draw their structures.

a. 3-methyl-3-pentanol

b. 2-methyl-2-pentanol

c. 3-methyl-2-pentanol

d. 2-methyl-3-pentanol

e. 2,4-dimethyl-3-pentanol

101. There are 11 structures (ignoring stereoisomerism) with the formula C_4H_8O that have no carbon branches. Draw the structures and identify the functional groups in each.

102. There are eight structures with the formula C_3H_7NO in which the O is part of a carbonyl group. Draw the structures and identify the functional groups in each.

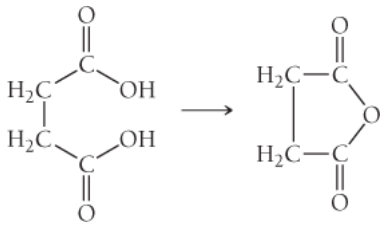
103. Explain why carboxylic acids are much stronger acids than alcohols.

104. The hydrogen at C-1 of 1-butyne is much more acidic than the hydrogens at C-1 in 1-butene. Explain.

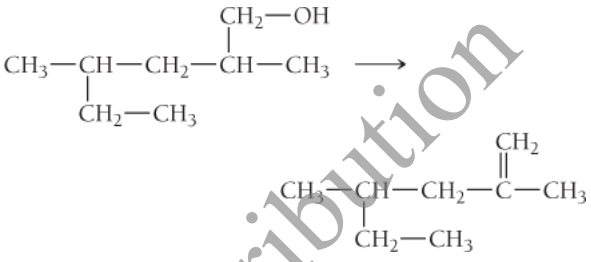
Challenge Problems

105. Determine the one or two steps it takes to get from the starting material to the product using reactions found in this chapter.

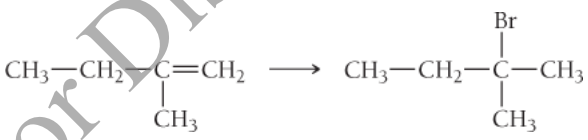
a.



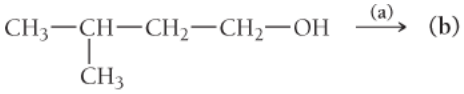
b.

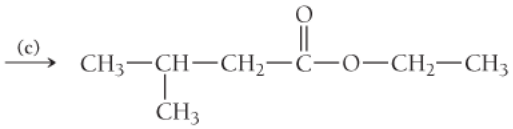


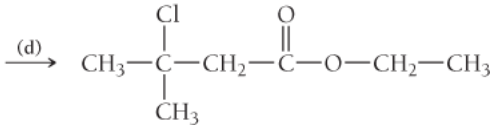
c.



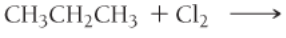
106. Given the following synthesis of ethyl 3-chloro-3-methylbutanoate, fill in the missing intermediates or reactants.

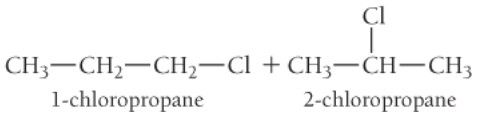






107. For the chlorination of propane, the two isomers shown here are possible.





Propane has six hydrogen atoms on terminal carbon atoms—called primary (1°) hydrogen atoms—and two hydrogen atoms on the interior carbon atom—called secondary (2°) hydrogen atoms.

a. If the two different types of hydrogen atoms were equally reactive, what ratio of 1-chloropropane to 2-chloropropane would we expect as monochlorination products?

b. The result of a reaction yields 55% 2-chloropropane and 45% 1-chloropropane. What can we conclude about the relative reactivity of the two different kinds of hydrogen atoms? Determine a ratio of the reactivity of one type of hydrogen atom to the other.

108. There are two isomers of C_4H_{10}. Suppose that each isomer is treated with Cl_2 and the products that have the composition $C_4H_8Cl_2$ are isolated. Find the number of different products that form from each of the original C_4H_{10} compounds. Do not consider optical isomerism.

109. Identify the compounds formed in the previous problem that are chiral.

110. Nitromethane has the formula CH_3NO_2, with the N bonded to the C and without O—O bonds. Draw its two most important contributing structures.

a. What is the hybridization of the C, and how many hybrid orbitals are in the molecule?

b. What is the shortest bond?

c. Between which two atoms is the strongest bond found?

d. Predict whether the HCH bond angles are greater or less than 109.5° and justify your prediction.

111. Free radical fluorination of methane is uncontrollably violent, and free radical iodination of methane is a very poor reaction. Explain these observations in light of bond energies.

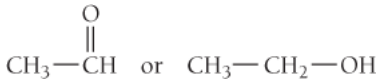
112. There are two compounds with the formula C_3H_6, one of which does not have a multiple bond. Draw its structure and explain why it is much less stable than the isomer with the double bond.

113. Consider molecules that have two carbons and two chlorines. Draw the structures of three of these with no dipole moment and two with a dipole moment.

Conceptual Problems

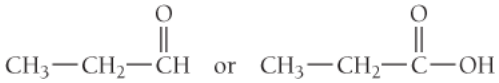
114. Pick the more oxidized structure from each pair.

a.



b. CH_3–CH_2–OH or CH_3–CH_3

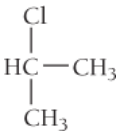
c.



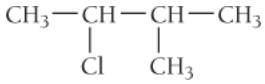
115. Draw the structure and name a compound with the formula C_8H_{18} that forms only one product with the formula $C_8H_{17}Br$ when it is treated with Br_2.

116. Determine whether each structure is chiral.

a.

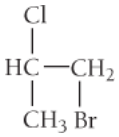


b.



c. $CH_3–CH_2–OH$

d.



Questions for Group Work

Active Classroom Learning

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

117. Have each group member select a different functional group. Individually, draw and name a compound containing your functional group. Pass your drawing to the group member on your right and your compound name to the group member on your left. Name the compound for the drawing you received and draw the compound whose name you received.

118. Using complete sentences, compare and contrast each of the following, mentioning at least two similarities and two differences for each:

a. salt and sugar

b. methane and 3-methylheptane

c. aldehydes and ketones

119. The octane rating for gasoline is a measurement of how readily a fuel combusts compared to 2,2,4-trimethylpentane, an isomer of octane.

a. Draw 2,2,4-trimethylpentane and verify that it is an isomer of octane.

b. Draw four other isomers of octane.

c. Select one of the isomers and draw it such that it looks different on the page but is still the exact same compound.

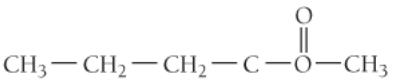
d. Name this isomer.

e. Define isomer using a complete sentence.

120. Working individually, have each group member select from the chapter a reaction characteristic of a particular organic functional group. Individually, write out your reaction with one of the following left as a blank: one reactant, one product, or reaction conditions. Pass your reaction to the group member on your right. Fill in the blank of the reaction you have received.

Data Interpretation and Analysis

121. Ester compounds often have a sweet, pleasant odor. Many characteristic fruit scents are largely due to the natural presence of one or more ester compounds. As such, artificial scents for foods are often composed of complex mixtures of various esters. The exact identity and ratio of ingredients that compose a particular scent are closely guarded secrets in the food and fragrance industry.
Suppose that you are a chemist working for a company that is creating a new line of air fresheners. The company is considering three scents: apple, pear, and pineapple. The project manager has asked you to prepare the ester compounds that are largely responsible for these scents. The structural formulas for these ester compounds are shown here:

Apple 

Pear $CH_3—C(=O)—O—CH_2—CH_2—CH_3$

Pineapple $CH_3—CH_2—CH_2—C(=O)—O—CH_2—CH_3$

To prepare these esters, you have been given the alcohols listed in the table and an adequate supply of all other necessary reagents, solvents, and equipment.

Alcohols for Air Freshener Project

Reagent	Molar mass (g/mol)	Density (g/mL)	Cost, per 1.00 L
methanol	32.04	0.79	$46.20
ethanol	46.07	0.79	$112.00
1-propanol	60.10	0.80	$72.70
1-butanol	74.12	0.81	$72.60

Use the structural formulas of the alcohols and information in the table to answer these questions:

a. Provide a name for each ester that you will prepare.

b. Draw the structure of each alcohol listed in the table.

c. Determine the procedure you will use to prepare each ester, using the reactions found in this chapter. (*Hint*: Recall that esters are derived from a carboxylic acid and an alcohol.)

d. Calculate the cost to prepare 100.0 g of each ester. Which one will be the most expensive to prepare? Which ester will be the least expensive? (Consider only the cost of the alcohols in the table, and disregard the costs of other reagents. Assume 100% yield for all reactions.)

Answers to Conceptual Connections

Cc 21.1 **(d)** The others are simply the same structure drawn in slightly different ways.

Cc 21.2 **(b)** This structure is the only one that contains a carbon atom (the one on the left) with four different substituent groups attached (a Br atom, a Cl atom, an H atom, and a CH_3 group).

Cc 21.3 **(b)** Pentane; because the longest continuous chain contains five carbon atoms.

Cc 21.4 **(c, d, a, b)** Oxidation includes the gain of oxygen or the loss of hydrogen.