UNITED ARAB EMIRATES
MINISTRY OF EDUCATION

المدرسة الإماراتية

2022-2023

Chemistry

Solutions Manual

United Arab Emirates Edition

Mc Graw Hill

Grade 12 Advanced

CHAPTER 21 SOLUTIONS MANUAL

Hydrocarbons

Section 21.1 Introduction to Hydrocarbons

pages 744–749

Section 21.1 Assessment

page 749

1. **Identify** three applications of hydrocarbons as a source of energy and raw materials.

   possible applications: fuel for home heating and starting materials for the synthesis of plastic products, films, and synthetic fabrics

2. **Name** an organic compound, and explain what an organic chemist studies.

   possible answer: methane; An organic chemist studies all carbon-containing compounds with the primary exceptions of carbon oxides, carbides, and carbonates.

3. **Identify** what each of the four molecular models highlight about a molecule.

   The molecular formula shows the atoms in the molecule. A structural formula shows the general arrangement of the atoms. The ball-and-stick model shows the geometry. The space-filling model shows a realistic picture of what the molecule actually looks like.

4. **Compare and contrast** saturated and unsaturated hydrocarbons.

   Saturated hydrocarbons are hydrocarbons that contain only single bonds between carbon atoms. Unsaturated hydrocarbons are hydrocarbons that contain at least one double or triple bond between carbon atoms.

5. **Describe** the process of fractional distillation.

   Fractional distillation is a process in which petroleum is separated into groups of components using boiling points as the separation mechanism.

6. **Infer** Some vegetable shortening products are described as "hydrogenated vegetable oil," which are oils that reacted with hydrogen in the presence of a catalyst. Form a hypothesis to explain why hydrogen reacted with the oils.

   Possible hypothesis: The oils react with hydrogen when double or triple bonds are broken and hydrogen atoms attach to the molecule.

7. **Interpret Data** Refer to **Figure 21.6.** What property of hydrocarbon molecules correlates to the viscosity of a particular fraction when it is cooled to room temperature?

   The greater the number of carbon atoms in the chain, the greater the viscosity of the fraction.

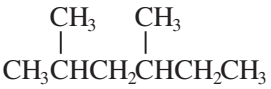
Section 21.2 Alkanes

pages 750–758

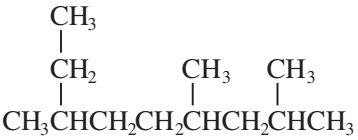
Practice Problems

pages 755–757

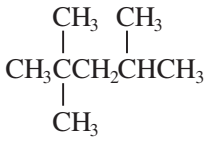
8. Use IUPAC rules to name the following structures.

   a. 

   2,4-dimethylhexane

   b. 

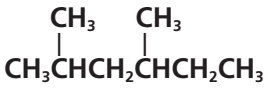
   2,2,4-trimethylpentane

   c. 

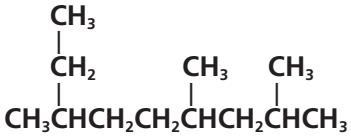
   2,4,7-trimethylnonane

9. Challenge Draw the structures of the following branched-chain alkanes.

a. 2,3-dimethyl-5-propyldecane

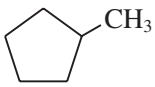


b. 3,4,5-triethyloctane



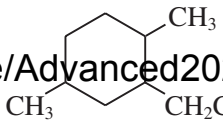
10. Use IUPAC rules to name the following structures.

a.



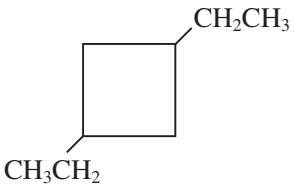
methylcyclopentane

b.



2-ethyl-1,4-dimethylcyclohexane

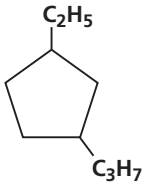
c.



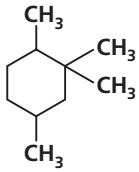
1,3-diethylcyclobutane

11. Challenge Draw the structures of the following cycloalkanes.

a. 1-ethyl-3-propylcyclopentane



b. 1,2,2,4-tetramethylcyclohexane



Section 21.2 Assessment

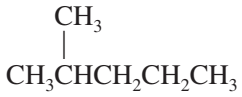
page 758

12. Describe the main structural characteristics of alkane molecules.

Alkanes are chain or ring hydrocarbons containing only single carbon-carbon covalent bonds.

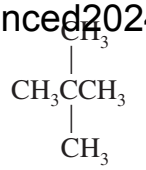
13. Name the following structures using IUPAC rules.

a.



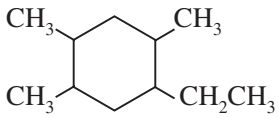
2-methylpentane

b.



2,2-dimethylpropane

c.



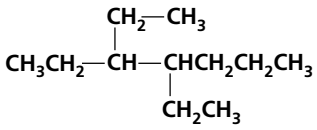
1-ethyl-2,4,5-trimethylcyclohexane

14. Describe the general properties of alkanes.

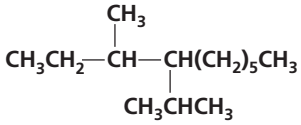
The C-C and C-H bonds are nonpolar, making alkanes insoluble in water, a polar solvent. Alkanes are good solvents for other nonpolar substances. The bonds are also strong and stable, making alkanes relatively unreactive.

15. Draw the molecular structure for each of the following.

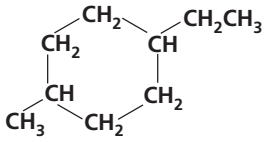
a. 3,4-diethylheptane



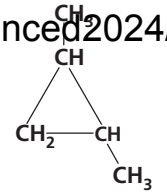
b. 4-isopropyl-3-methyldecane



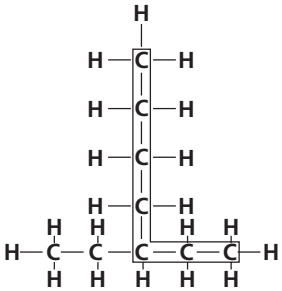
c. 1-ethyl-4-methylcyclohexane



d. 1,2-dimethylcyclopropane



16. Interpret Chemical Structures Why is the name 3-butylpentane incorrect? Based on this name, write the structural formula for the compound. What is the correct IUPAC name for 3-butylpentane?



The longest continuous carbon chain contains seven carbon atoms, not five carbon atoms. Parent chain has seven carbon atoms with an ethyl group on carbon 3. 3-ethylheptane.

Section 21.3 Alkenes and Alkynes

pages 759–764

Practice Problems

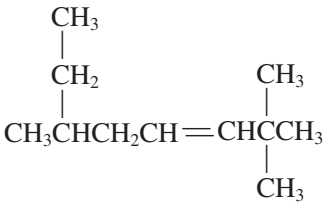
page 761

17. Use IUPAC rules to name the following structures.

a. $CH_3CH{=}CHCHCH_3$ (with CH_3 branch)

4-methyl-2-pentene

b.



2,2,6-trimethyl-3-octene

18. Challenge Draw the structure of 1,3-pentadiene.

$CH_2{=}CH-CH{=}CH-CH_3$

$CH_2{=}CHCH{=}CHCH_3$

Section 22.3 Assessment

page 764

19. Describe how the molecular structures of alkenes and alkynes differ from the structure of alkanes.

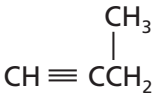
Alkanes have single bonds in their structure. Alkenes have at least one double bond in their structure. Alkynes have at least one triple bond in their structure.

20. Identify how the chemical properties of alkenes and alkynes differ from those of alkanes.

Alkenes and alkynes are much more reactive than alkanes. This is because they have regions of concentrated electron density that attract reactants of opposite charge.

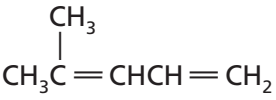
21. Name the structures shown using IUPAC rules.

a.



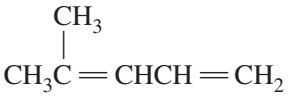
1-butyne

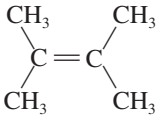
b.



5-methyl-3-heptene

22. Draw the molecular structure of 4-methyl-1,3-pentadiene and 2,3-dimethyl-2-butene.





23. Infer how the boiling and freezing points of alkynes compare with those of alkanes with the same number of carbon atoms. Explain your reasoning, then look up data to see if it supports your idea.

Because alkynes are slightly more polar, they generally have higher melting and boiling points than alkanes. Data support this hypothesis.

24. Predict What geometric arrangement would you expect from the bonds surrounding the carbon atoms in alkanes, alkenes, and alkynes? (Hint: VSEPR theory can be used to predict the shape.)

VSEPR theory predicts the following geometric bond arrangements.
alkane: tetrahedral shape; alkene: trigonal planar shape; alkyne: linear shape

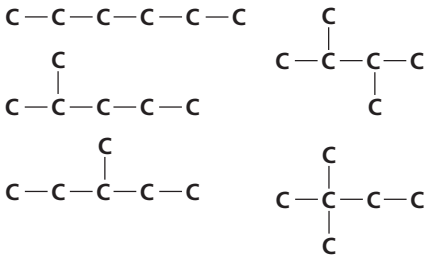
Section 21.4 Hydrocarbon Isomers

pages 765–769

Section 21.4 Assessment

page 769

25. Draw all of the structural isomers possible for the alkane with the molecular formula C_6H_{14}. Show only the carbon chains.

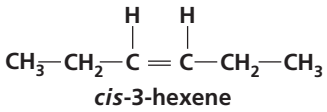


Answers will include 5 structural isomers: hexane, 2-methylpentane, 3-methylpentane, 2,3-dimethylbutane, and 2,2-dimethylbutane.

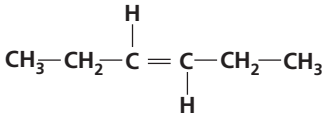
26. Explain the difference between structural isomers and stereoisomers.

Structural isomers differ from each other in the order in which their atoms are bonded to each other, whereas stereoisomers have their atoms bonded in the same order but they are arranged differently in space.

27. Draw the structures of *cis*-3-hexene and *trans*-3-hexene.



***cis*-3-hexene**



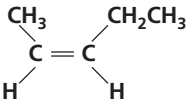
***trans*-3-hexene**

In *cis*-3-hexene, the hydrogen atoms attached to the doubly-bonded carbons are on the same side of the carbon chain. In the *trans* form, the hydrogen atoms are on opposite sides of the carbon chain.

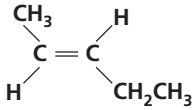
28. Infer why living organisms can make use of only one chiral form of a substance.

In general, living organisms make use of only one chiral form of a substance because only this form fits the active site of an enzyme.

29. Evaluate A certain reaction yields 80% *trans*-2-pentene and 20% *cis*-2-pentene. Draw the structures of these two geometric isomers, and develop a hypothesis to explain why the isomers form in the proportions cited.



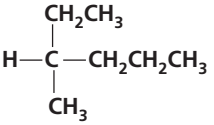
***cis*-pentene**

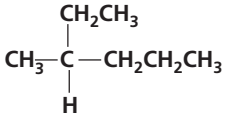


***trans*-pentene**

More of the *trans* isomer forms because its structure allows the bulky methyl and ethyl groups to be farther apart than in the *cis* structure.

30. Formulate Models Starting with a single carbon atom, draw two different optical isomers by attaching the following atoms or groups to the carbon: —H, —CH_3, —CH_2CH_3, —$CH_2CH_2CH_3$





Structures should show the listed groups attached to a single carbon atom. They should differ in that two of the attached groups should be reversed in space.

Section 21.5 Aromatic Compounds

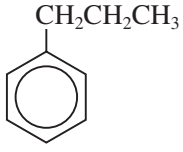
pages 770–774

Practice Problems

page 773

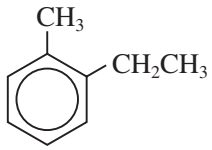
31. Name the following structures.

a.



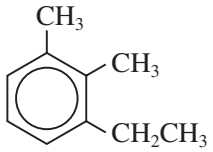
propylbenzene

b.



1-ethyl-2-methylbenzene

c.



1-ethyl-2,3-dimethylbenzene

32. Challenge Draw the structure of 1,4-dimethylbenzene

Section 21.5 Assessment

page 774

33. Explain benzene's structure and how it makes the molecule unusually stable.

The electron pairs in benzene are delocalized and shared by all six carbon atoms in the ring. Benzene is relatively unreactive because the electrons are harder to pull away from six carbon atoms.

34. Explain how aromatic hydrocarbons differ from aliphatic hydrocarbons.

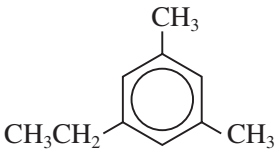
Aromatic compounds contain rings in their structures and aliphatic hydrocarbons are straight-chain or branched-chain structures.

35. Describe the properties of benzene that made chemists think it was not an alkene with several double bonds.

Benzene is much less reactive than alkenes with multiple double bonds, which usually are very unstable. When benzene did react, the reactions were not similar to those of alkenes.

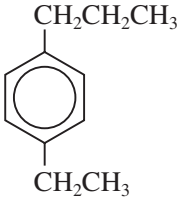
36. Name the following structures.

a.



1-ethyl-3,5-dimethylbenzene

b.



1-ethyl-4-propylbenzene

37. Explain why the connection between benzopyrene and cancer was significant.

Benzopyrene was the first known carcinogen and exposure to it was occupation related. After it was discovered to be a carcinogen, measures could be taken to protect the workers. The discovery also helped chemists and medical professionals to look for other substances that could be potentially hazardous for workers.

Chapter 21 Assessment

pages 778–781

Section 21.1

Mastering Concepts

38. Organic Chemistry Why did Wohler's discovery lead to the development of the field of organic chemistry?

Chemists realized that it was possible to synthesize organic compounds without a vital force.

39. What is the main characteristic of an organic compound?

Organic compounds contain the element carbon.

40. What characteristic of carbon accounts for the large variety of organic compounds?

Carbon is able to form four strong covalent bonds, including bonds with other carbon atoms.

41. Name two natural sources of hydrocarbons.

petroleum and natural gas

42. Explain what physical property of petroleum compounds is used to separate them during fractional distillation.

boiling point

43. Explain the difference between saturated hydrocarbons and unsaturated hydrocarbons.

Saturated hydrocarbons contain all single carbon-carbon bonds. Unsaturated hydrocarbons contain one or more double or triple carbon-carbon bonds.

Mastering Problems

44. Distillation Rank the compounds listed in **Table 21.7** in the order in which they will be distilled out of a mixture. Rank the compounds in order of first to distill from mixture to last to distill from mixture.

Alkane Boiling Points

Compound	Boiling Point (°C)
hexane	68.7
methane	−161.7
Octane	125.7
butane	−0.5
propane	−42.1

methane, propane, butane, hexane, octane (in order of boiling point, lowest to highest)

45. How many electrons are shared between two carbon atoms in each of the following carbon-carbon bonds?

a. single bond

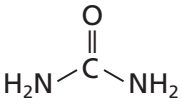
2 electrons

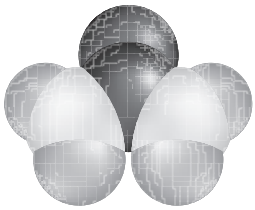
b. double bond

4 electrons

c. triple bond

6 electrons





46. Figure 21.29 shows two models of urea, a molecule that Friedrich Wöhler first synthesized in 1828.

a. Identify the types of models shown.

structural formula and space-filling model

b. Is urea an organic or an inorganic compound? Explain your answer.

It is an organic compound because it contains carbon and it is not one of the groups that is an exception—carbon oxide, carbide, or carbonate.

47. Molecular Models Molecules are modeled using molecular formulas, structural formulas, ball-and-stick models, and space-filling models. What are the advantages and disadvantages of each model?

Molecular models show the type of atoms in the molecule, but they do not show the geometry of the molecule.

Structural formulas show the type of atoms in the molecule and the general arrangement of the atoms, but not the exact geometry.
Ball-and-stick models show the types of atoms in the molecule and the general arrangement, but not the exact geometry.

Space-filling models show a realistic picture of the molecule, but it is difficult to determine the types of bonds in the molecule and if the molecule is large, it is difficult to see all of the atoms in the molecule.

Section 21.2

Mastering Concepts

48. Describe the characteristics of a homologous series of hydrocarbons.

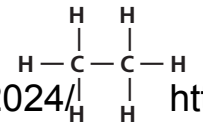
It is a series of compounds that differ from each other by a repeating unit and have a fixed numerical relationship among the numbers of atoms.

49. Fuels Name three alkanes and describe an application for each.

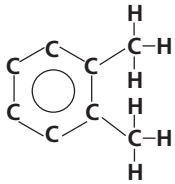
Methane—fuel for cooking and heating; propane—fuel for cooking and heating; butane—small lighters and some torches

50. Draw the structural formula of each of the following.

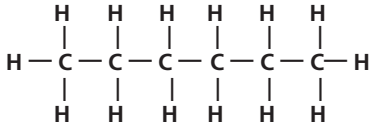
a. ethane



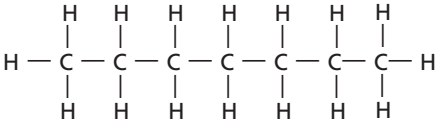
b. hexane



c. propane



d. heptane



51. Write the condensed structural formulas for the alkanes in the previous question.

a. CH_3CH_3

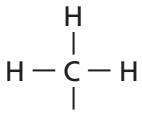
b. $CH_3(CH_2)_4CH_3$

c. $CH_3CH_2CH_3$

d. $CH_3(CH_2)_5CH_3$

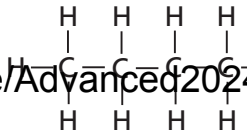
52. Write the name and draw the structure of the alkyl group that corresponds to each of the following alkanes.

a. methane



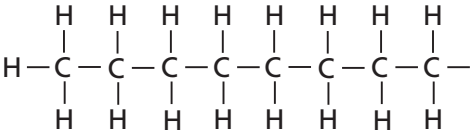
methyl

b. butane



butyl

c. octane



octyl

53. How does the structure of a cycloalkane differ from that of a straight-chain or branched-chain alkane?

A cycloalkane contains a ring of carbon atoms. Each carbon in a cycloalkane has two hydrogens bonded to it, but terminal carbons in straight-chain alkanes each bond to three hydrogen atoms; as a result, cycloalkane molecules have two fewer hydrogen atoms compared to alkane molecules with equal numbers of carbons.

54. Freezing and Boiling Points Use water and methane to explain how intermolecular attractions generally effect the boiling and freezing points of a substance.

Methane molecules are nonpolar and they do not form hydrogen bonds with other methane molecules. Water molecules are polar and freely form hydrogen bonds with other water molecules. Because of the attraction between molecules in water, water has a higher boiling point and a higher melting point than methane.

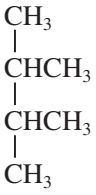
Mastering Problems

55. Name the compound represented by each of the following structural formulas.

a. $CH_3CH_2CH_2CH_2CH_3$

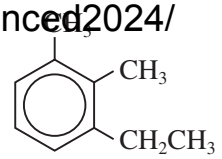
pentane

b.



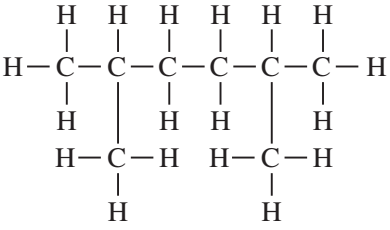
3-methylpentane

c.



2,5-dimethylhexane

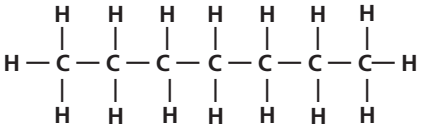
d.



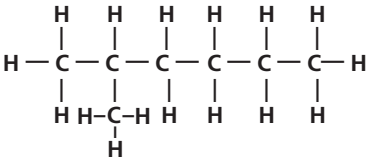
2,3-dimethylbutane

56. Alkanes Draw full structural formulas for the following compounds.

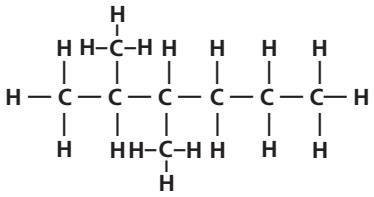
a. heptane



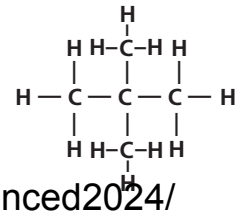
b. 2-methylhexane



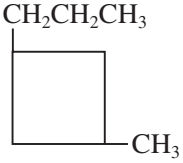
c. 2,3-dimethylpentane



d. 2,2-dimethylpropane

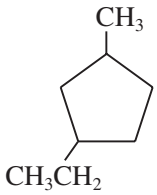


b. $CH_2CH_2CH_3$



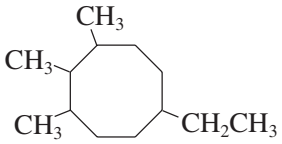
1-ethyl-3-methylcyclopentane

c.



1-methyl-3-propylcyclobutane

d.

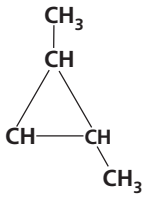


6-ethyl-1,2,3-trimethylcyclooctane

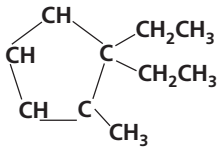
Section 21.3

57. Draw condensed structural formulas for the following compounds. Use line structures for rings.

a. 1,2-dimethylcyclopropane

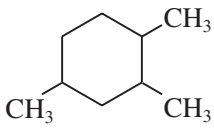


b. 1,1-diethyl-2-methylcyclopentane



58. Name the compound represented by each of the following structural formulas.

a.



1,2,4-trimethylcyclohexane

Mastering Concepts

59. Explain how alkenes differ from alkanes. How do alkynes differ from both alkenes and alkanes?

Alkanes contain only single bonds between carbon atoms in the molecule. Alkenes contain at least one double bond between carbon atoms in the molecule. Alkynes contain at least one triple bond between carbon atoms in a molecule.

60. The name of a hydrocarbon is based on the name of the parent chain. Explain how the determination of the parent chain when naming alkenes differs from the same determination when naming alkanes.

When naming alkanes, the parent chain is the longest continuous carbon chain. When naming alkenes, the parent chain is the longest continuous carbon chain that includes the carbon atoms linked by a double bond.

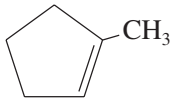
Mastering Problems

61. Alkenes Name the compound represented by each of the following condensed structural formulas.

a. $CH_3C(CH_3)=CHCH_3$

2-methyl-2-butene

b.

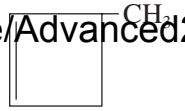


2-ethyl-1-butene

c. $CH_3CH_2C(CH_2CH_3)=CH_2$

1-methylcyclopentene

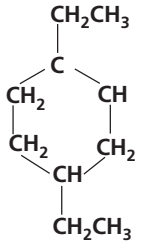
d.



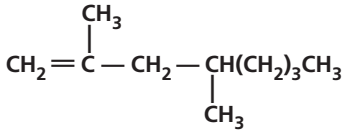
3-methylcyclobutene

62. Draw condensed structural formulas for the following compounds. Use line structures for rings.

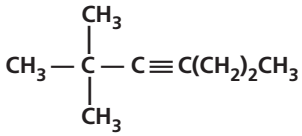
a. 1,4-diethylcyclohexene



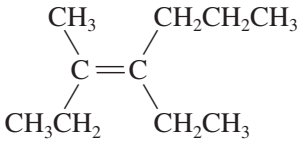
b. 2,4-dimethyl-1-octene



c. 2,2-dimethyl-3-hexyne



63. Name the compound represented by the following condensed structural formula.



4-ethyl-3-methyl-3-heptene

Section 21.4

Mastering Problems

64. How are two isomers alike, and how are they different?

Isomers have the same molecular formula but different structures. They may have very different chemical and physical properties.

65. Describe the difference between *cis*- and *trans*-isomers in terms of geometrical arrangement.

***Cis* isomers have the largest groups on the carbons in the double bond on the same side of the bond; in *trans* isomers they are on opposite sides.**

66. What are the characteristics of a chiral substance?

A chiral substance has both right- and left-handed forms. Chiral substances have at least one carbon atom bonded to four different groups and are therefore asymmetrical.

67. Light How does polarized light differ from ordinary light, such as light from the Sun?

The waves of polarized light all vibrate in one plane; in ordinary light, they vibrate in all possible planes.

68. How do optical isomers affect polarized light?

They rotate polarized light.

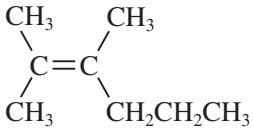
Mastering Problems

69. Identify the pair of structural isomers in the following group of condensed structural formulas.

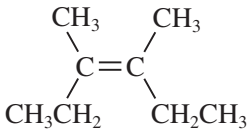
Student answers may include any two structures except b and d, which are identical.

70. Identify the pair of geometric isomers among the following structures. Explain your selections. Explain how the third structure is related to the other two.

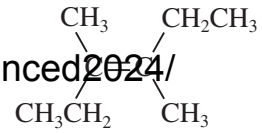
a.



b.

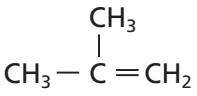


c.

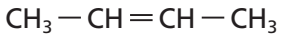


b and c are geometric isomers. They represent a *cis/trans* pair of isomers. a is a structural isomer of both b and c.

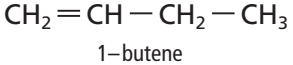
71. Draw condensed structural formulas for four different structural isomers with the molecular formula C_4H_8.



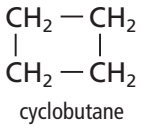
methyl propene



2–butene



1–butene



cyclobutane

Student answers should show condensed structural formulas for cyclobutane, 1-butene, 2-butene, and 2-methylpropene.

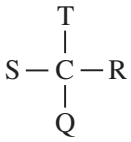
72. Draw and label the *cis*- and *trans*-isomers of the molecule represented by the following condensed formula.

$CH_3CH=CHCH_2CH_3$

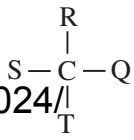
The two hydrogen atoms bonded to the doubly-bonded carbons are on the same side of the carbon chain for the *cis* isomer and on opposite sides of the carbon chain for the *trans* isomer.

73. Isomers Three of the following structures are exactly alike, but the fourth represents an optical isomer of the other three. Identify the optical isomer, and explain how you made your choice.

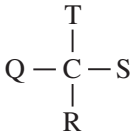
a.



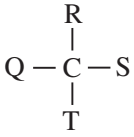
b.



c.



d.



a is an optical isomer of b, c, and d. a is not superimposable with b, c, or d.

Section 21.5

Mastering Concepts

74. What structural characteristic do all aromatic hydrocarbons share?

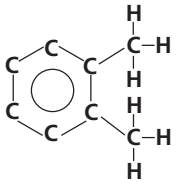
They all have a ring structure in the molecule.

75. What are carcinogens?

Carcinogens are substances that can cause cancer.

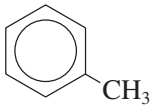
Mastering Problems

76. Draw the structural formula of 1,2-dimethylbenzene.



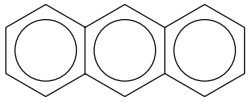
77. Name the compound represented by each of the following structural formulas.

a.



methylbenzene (toluene)

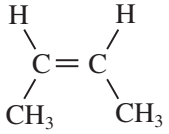
b.

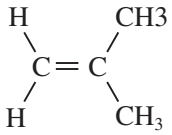


anthracene

Mixed Review

78. Do the following structural formulas represent the same molecule? Explain your answer.





No. They are structural isomers.

79. How many hydrogen atoms are in an alkane molecule with nine carbon atoms? How many are in an alkene with nine carbon atoms and one double bond?

20 hydrogen atoms; 18 hydrogen atoms

80. The general formula for alkanes is C_nH_{2n+2}. Determine the general formula for cycloalkanes.

C_nH_{2n}

81. Manufacturing Why are unsaturated hydrocarbons more useful than saturated hydrocarbons as starting materials in chemical manufacturing?

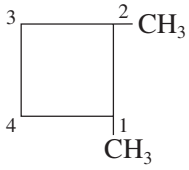
Unsaturated hydrocarbons are much more reactive.

82. Isomers Is cyclopentane an isomer of pentane? Explain your answer.

No. Cyclopentane (C_5H_{10}) and pentane (C_5H_{12}) have different molecular formulas.

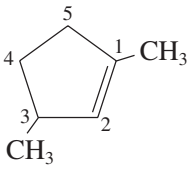
83. Determine whether each of the following structures shows the correct numbering. If the numbering is incorrect, redraw the structure with the correct numbering.

a.



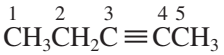
Yes

b.



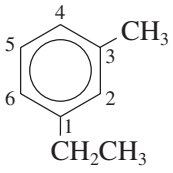
No, it should be numbered from the opposite end.

c.



No. The ring should be numbered clockwise starting with the carbon shown as number 2.

d.



Yes

84. Chemical Formulas Why do chemists use structural formulas for organic compounds rather than molecular formulas such as C_5H_{12}?

Molecular formulas cannot differentiate between isomers. Many different compounds could have the formula C_5H_{12}.

85. Which would you expect to have more similar physical properties, a pair of structural isomers or a pair of stereoisomers? Explain your reasoning.

Structural isomers may have vastly different physical properties because they have completely different arrangements of the carbon skeleton. Stereoisomers (geometric and optical isomers) have the same carbon skeleton but different orientations in space. Geometric isomers have different properties; optical isomers differ only in the direction of rotation of polarized light and in chemical reactions that distinguish between isomers. Therefore, optical isomers would have more similar properties.

86. Explain why numbers are needed in the IUPAC names of many unbranched alkenes and alkynes but not in the names of unbranched alkanes.

Numbers are needed to identify the locations of the double and triple bonds.

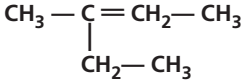
87. A compound with two double bonds is called a diene. The name of the structure shown is 1,4-pentadiene. Apply your knowledge of IUPAC nomenclature to draw the structure of 1,3-penadiene.

$H_2C = CH - CH_2 - CH = CH_2$

Think Critically

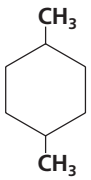
88. Determine which two of the following names cannot be correct, and draw the structures of the molecules.

a. 2-ethyl-2-butene



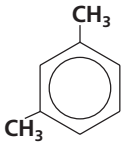
Correct name is 3-methyl-2-pentene.

b. 1,4-dimethylcyclohexene



Name is correct.

c. 1,5-dimethylbenzene



Correct name is 1,3-dimethylbenzene.

89. Infer The sugar glucose is sometimes called dextrose because a solution of glucose is known to be dextrorotatory. Analyze the word *dextrorotatory*, and suggest what the word means.

The prefix *dextro-* means "to the right," and the suffix *rotatory* means "rotates." Therefore, the natural form of glucose is chiral and rotates the plane of polarized light to the right.

90. Interpret Scientific Illustrations Draw Kekulé's structure of benzene, and explain why it does not truly represent the actual structure.

The structure shows localized electrons in the double bonds rather than delocalized electrons.

91. Recognize Cause and Effect Explain why alkanes such as hexane and cyclohexane are effective at dissolving grease, whereas water is not.

Grease and alkanes are both nonpolar. Water is polar. Like dissolves like.

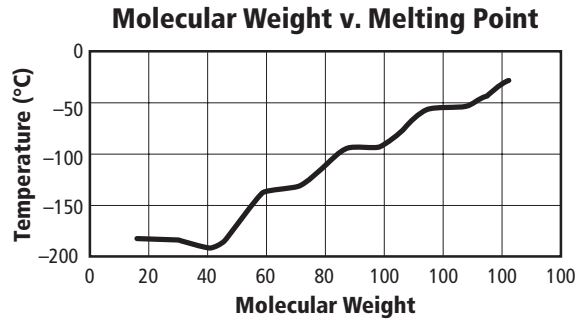
92. Explain Use **Table 21.8** to construct a statement explaining the relationship between numbers of carbon atoms and boiling points of the members of the alkane series shown.

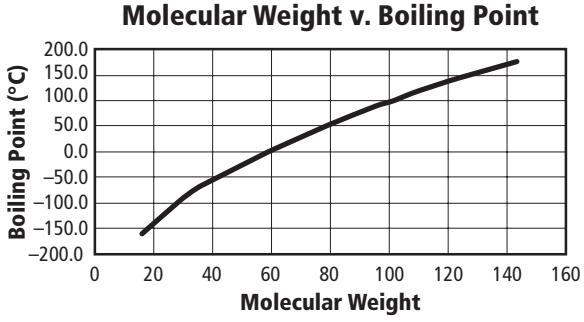
Data for Selected Alkanes		
Name	**Melting Point (°C)**	**Boiling Point (°C)**
CH_4	–182	–162
C_2H_6	–183	–89
C_3H_8	–188	–42
C_4H_{10}	–138	–0.5
C_5H_{12}	–130	36
C_6H_{14}	–95	69
C_7H_{16}	–91	98
C_8H_{18}	–57	126
C_9H_{20}	–54	151
$C_{10}H_{22}$	–29	174

As the number of carbon atoms increases in the chain, the boiling point increases.

93. Graph the information given in **Table 21.8.** Predict what the boiling and melting points of the 11- and 12-carbon alkanes will be. Look up the actual values and compare your predictions to the actual values.

Student predictions will vary, but should approximate accepted values.



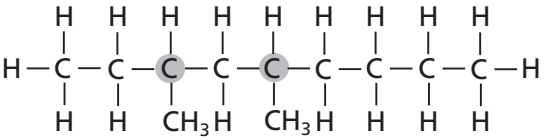


The actual boiling point of $C_{11}H_{24}$ is 196°C. The actual boiling point of $C_{11}H_{24}$ is 216°C.

Challenge Problem

94. Chiral Carbons Many organic compounds have more than one chiral carbon. For each chiral carbon in a compound, a pair of stereoisomers can exist. The total number of possible isomers for the compound is equal to *2n*, where *n* is the number of chiral carbons. Draw each structure, and determine how many stereoisomers are possible for each compound named below.

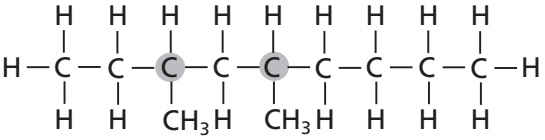
a. 3,5-dimethylnonane



3,5- dimethylnonane
2 chiral carbon atoms

2 chiral carbons; $2^n = 2^2 = 4$

b. 3,7-dimethyl-5-ethyldecane



3,5- dimethylnonane
2 chiral carbon atoms

3 chiral carbons; $2^n = 2^3 = 8$

Cumulative Review

95. What element has the following ground-state electron configuration: $[Ar]4s^23d^6$? (*Chapter 5*)

iron

96. What is the charge of an ion formed from the following families? (*Chapter 7*)

a. alkali metals

1+

b. alkaline earth metals

2+

c. halogens

1–

97. Write the chemical equations for the complete combustion of ethane, ethene, and ethyne into carbon dioxide and water. *(Chapter 10)*

ethane: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$;

ethene: $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$;

ethyne: $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

Additional Assessment

98. Gasoline For many years, a principal anti-knock ingredient in gasoline was the compound tetraethyllead. Do research to learn about the structure of this compound, the history of its development and use, and why its use was discontinued in the United States. Find out if it is still used as a gasoline additive elsewhere in the world.

Student answers should include a drawing of the structure of tetraethyllead ($Pb(CH_2CH_3)_4$), a discussion of when it was used in the United States, what its health hazards are, and a listing of some areas in the world where it is still added to gasoline.

99. Perfume The musk used in perfumes and colognes contains many chemical compounds, including large cycloalkanes. Research and write a short report about the sources used for natural and synthetic musk compounds in these consumer products.

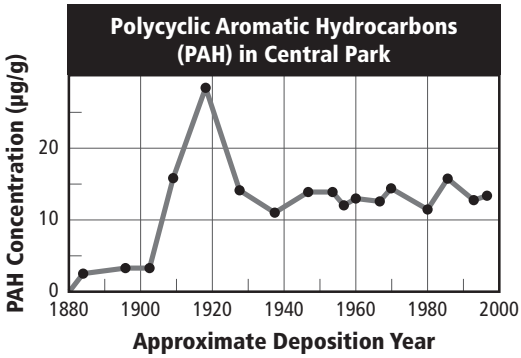
The natural source of the musk that is used in perfumes is the male musk deer. The primary odorous compound is 3-methylcyclopentadecanone, which is synthesized in the perfume and cologne industries.

Document-Based Questions

Polycyclic Aromatic Hydrocarbons PAH compounds are naturally occurring, but human activities can increase the concentrations in the environment. Soil samples were collected to study PAH compounds. The core sections were dated using radionuclides to determine when each section was deposited.

Figure 21.30 shows the concentration of polycyclic aromatic hydrocarbons (PAH) detected in Central Park in New York City.

Data obtained from: Yan, B. et al, 2005. *Environmental Science Technology* 39 (18): 7012–7019



100. Compare the average PAH concentrations before 1905 and after 1925.

average before 1905 about 3; average after 1925 about 13.

101. PAH compounds are produced in small amounts by some plants and animals, but most come from human activities such as burning fossil fuels. Infer why the PAH levels were relatively low in the late 1800s and early 1900s.

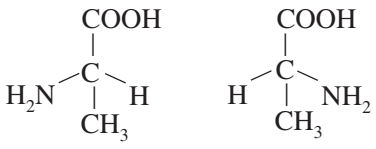
The primary fuel burned by humans at this time was wood. The PAH levels began to increase when fossil fuels replaced wood as a fuel source.

Standardized Test Practice

pages 782–7830

Multiple Choice

1. Alanine, like all amino acids, exists in two forms:



Almost all of the amino acids found in living organisms are in the L-form. Which term best describes L-Alanine and D-Alanine with respect to one another?

a. structural isomers
b. geometric isomers
c. optical isomers
d. stereoisotopes

c

2. Which does NOT affect reaction rate?

a. catalysts
b. surface area of reactants
c. concentration of reactants
d. reactivity of products

d

3. What is the molality of a solution containing 0.25 g of dichlorobenzene ($C_6H_4C_{l2}$) dissolved in 10.0 g of cyclohexane (C_6H_{12})?

a. 0.17 mol/kg
b. 0.014 mol/kg
c. 0.025 mol/kg
d. 0.00017 mol/kg

a

Solution:

$$m = \frac{\text{moles of solute}}{\text{kg solvent}}$$

solute: $C_6H_4Cl_{l2}$; molar mass of $C_6H_4Cl_{l2}$ = 146.99 g/mol

solvent: C_6H_{12}; kg solvent = $\frac{1kg}{1000g}$

= 0.01 kg C_6H_{12}

Determine the number moles of solvent.

02.5 g $C_6H_4Cl_2 \times \frac{1 \text{ mol } C_6H_4Cl_2}{146.99 \text{ g } C_6H_4Cl_2}$ 1.70 × 1.70 × 10^{-3} mol $C_6H_4Cl_2$

$$m = \frac{1.70 \times 10^{-3} \text{ mol } C_6H_4Cl_2}{0.01 \text{ kg } C_6H_{12}} = 0.17 \text{ mol/kg}$$

Use the table below to answer Questions 4–6.

Data for Various Hydrocarbons

Name	Number of C Atoms	Number of H Atoms	Melting Point (°C)	Boiling Point (°C)
Heptane	7	16	–90.6	98.5
1-Heptene	7	14	–119.7	93.6
1-Heptyne	7	12	–81	99.7
Octane	8	18	–56.8	125.6
1-Octene	8	16	–101.7	121.2
1-Octyne	8	14	–79.3	126.3

4. Based on the information in the table, what type of hydrocarbon becomes a gas at the lowest temperature?

a. alkane
b. alkene
c. alkyne
d. aromatic

b

5. If n is the number of carbon atoms in the hydrocarbon, what is the general formula for an alkyne with one triple bond?

a. C_nH_{n+2}
b. C_nH_{2n+2}
c. C_nH_{2n}
d. C_nH_{2n-2}

d

6. It can be predicted from the table that nonane will have a melting point that is

a. greater than that of octane.
b. less than that of heptane.
c. greater than that of decane.
d. less than that of hexane.

a

7. At a pressure of 1.00 atm and a temperature of 20°C, 1.72 g CO_2 will dissolve in 1 L of water. How much CO_2 will dissolve if the pressure is raised to 1.35 atm and the temperature stays the same?

a. 2.32 g/L
b. 1.27 g/L

c. 0.785 g/L
d. 0.431 g/L

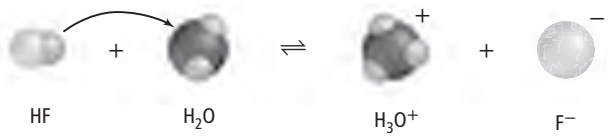
a

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

$S_2 = S_1(\frac{P_2}{P_1})$ = 1.72 g/L(1.35 atm/1.00 atm) = 2.32 g/L

Because the volume is 1 L, 2.32 g will dissolve.

Use the diagram below to answer Question 8.



8. In the forward reaction, which substance is the Brønsted-Lowry acid?
a. HF
b. H_2O
c. H_3O^+
d. F^-

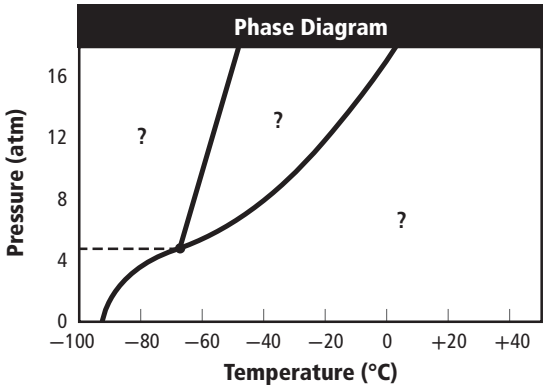
a

9. Which does NOT describe what happens as a liquid boils?
a. The temperature of the system rises.
b. Energy is absorbed by the system.
c. The vapor pressure of the liquid is equal to atmospheric pressure.
d. The liquid is entering the gas phase.

a

Short Answer

Use the diagram below to answer Questions 10–12.



10. What state of matter is located at a temperature of −80°C and a pressure of 10 atm?

solid

11. What are the temperature and pressure when the substance is at its triple point?

approximately –65° C and 4.8 atm

12. Describe the changes in molecular arrangement that occur when the pressure is increased from 8 atm to 16 atm while the temperature is held constant at 0°C.

The substance is changing from a gas to a liquid as the pressure is increased; as the particles become more compact they lose kinetic energy, become more ordered, and are spaced closer together.

Extended Response

Use the data table below to answer Questions 13 and 14.

Experimental Data for the Reaction between A and B

[A] Initial	[B] Initial	Initial rate (mol/L•s)
0.10 M	0.10 M	7.93
0.30 M	0.10 M	23.79
0.30 M	0.20 M	95.16

13. Find the values of m and n for the rate law expression $rate = k[A]^m[B]^n$.

To solve for the exponents in the rate law, use a set of conditions in the table. Compare the ratio of concentrations of a reactant to the ratio of different rates for the same trials.

For the exponent of [A]: use the first and second trials

$Rate_2/rate_1 = ([A]_2/[A]_1)^m = 23.79/7.93 = 3.00$; $(.30/.10)^m = 3.00$; $3^m = 3$; $m = 1$

Similarly, compare the rates of reactions when the concentration of B changes:

$Rate_3/rate_2 = ([B]_3/[B]_2)^n = 95.16/23.79 = 4.00$; $(.20/.10)^n = 4.00$; $2^n = 4$; $n = 2$

$Rate = k[A][B]^2$

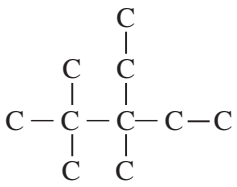
14. Determine the value of k for this reaction.

To find the value of k_{eq}, plug any set of concentrations for A and B determined in a single trial into the rate expression determined in question 13.

k = rate/([A][B]^2); k = 7.93 mol/(L−s) /((.10 mol/L)(.10 mol/L)^2) = 7930 L^2/(s-mol^2)

rate = 7930[A][B]^2 mol/(L · s)

SAT Subject Test: Chemistry

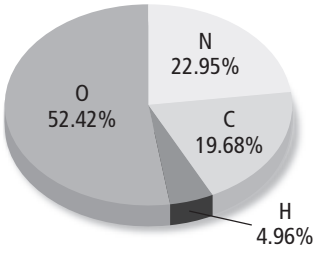


15. What is the name of the compound whose skeletal formula is shown above?

a. 2,2,3-trimethyl-3-ethylpentane
b. 3-ethyl-2,4,4-trimethylpentane
c. 2-butyl-2-ethylbutane
d. 3-ethyl-2,2,3-trimethylpentane
e. 2,2-dimethy, 3-diethyl, 3-methylpropane

d

Use the graph below to answer Questions 16 and 17.



16. What is the formula for this compound?

a. $C_5H_{20}N_4O_2$
b. $C_8H_2N_9O_{11}$
c. $C_{1.6}H_5N_{1.6}O_{3.3}$
d. CH_3NO_2
e. $C_2H_5N_2O_5$

d

Solution:

Assume a 100.0 g sample.

N: 22.95 g N $\times \frac{1 \text{ mol n}}{14.01 \text{ g N}} = 1.638$ mol N

C: 19.68 g C $\times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 1.639$ mol C

H: 4.96 g H $\times \frac{1 \text{ mol H}}{14.01 \text{ g H}} = 4.921$ mol H

O: 52.42 g O $\times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.276$ mol O

Empirical Formula:

N: $\frac{1.638 \text{ mol N}}{1.638} = 1.000$

C: $\frac{1.639 \text{ mol C}}{1.638} = 1.001$

H: $\frac{4.921 \text{ mol H}}{1.638} = 3.000$

O: $\frac{3.276 \text{ mol O}}{1.638} = 2.000$

The formula is CH_3NO_2.

17. How many grams of nitrogen would be present in 475 grams of this compound?

a. 33.93 g
b. 52.78 g
c. 67.86 g
d. 109.0 g
e. 110.5 g

d

Solution:

0.2295 × 475 g = 109 g

CHAPTER 22 SOLUTIONS MANUAL

Substituted Hydrocarbons and Their Reactions

Section 22.1 Alkyl Halides and Aryl Halides

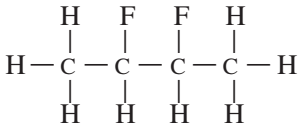
pages 786–791

Practice Problems

page 788

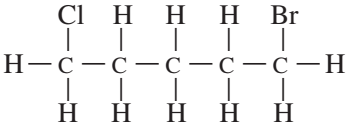
Name the alkyl or aryl halide whose structure is shown.

1.



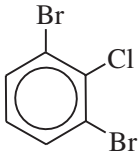
2,3-difluorobutane

2.



1-bromo-3-chloropentane

3.



1,3-dibromo-2-cholorbenzene

Section 22.1 Assessment

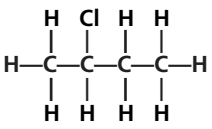
page 791

4. Compare and contrast alkyl halides and aryl halides.

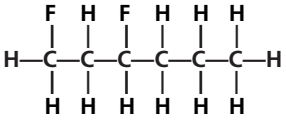
An alkyl halide is a substituted hydrocarbon that is covalently bonded to an aliphatic carbon atom. An aryl halide is a substituted hydrocarbon that contains a halogen bonded to a benzene ring or other aromatic compound.

5. Draw structures for the following molecules.

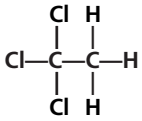
a. 2-chlorobutane



b. 1,3-difluorohexane



c. 1,1,1-trichloroethane



d. 4-bromo-1-chlorobenzene

6. Define functional group and name the group present in each of the following structures. Name the type of organic compound each substance represents.

a. $CH_3CH_2CH_2OH$

hydroxyl group; alcohol

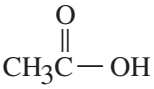
b. CH_3CH_2F

fluoro group; alkyl halide

c. $CH_3CH_2NH_2$

amino group; amine

d.



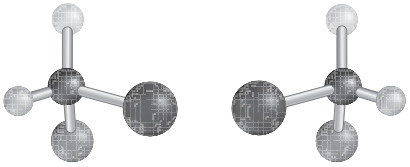
carboxyl group; carboxylic acid

A functional group is an atom or group of atoms that reacts in a certain way.

7. Evaluate How would you expect the boiling points of propane and 1-chloropropane to compare? Explain your answer.

The boiling point of 1-chloropropane should be higher than that of propane. The molecules in 1-chloropropane should form more temporary dipoles than the molecules in propane molecules.

8. Interpret Scientific Illustrations Examine the pair of substituted hydrocarbons illustrated at right, and decide whether it represents a pair of optical isomers. Explain your answer.



They are optical isomers. They are not superimposable; however, their structures have chiral carbons and are mirror images of each other.

Section 22.2 Alcohols, Ethers, and Amines

pages 792–795

Section 22.2 Assessment

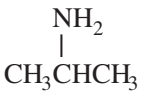
page 795

9. Identify two elements that are commonly found in functional groups.

Possible answers: oxygen, nitrogen, fluorine, chlorine, bromine, iodine, sulfur, and phosphorus

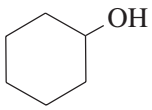
10. Identify the functional group present in each of the following structures. Name the substance represented by each structure.

a.



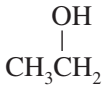
–NH_2 represents the amino functional group; isopropyl-amine, 2-propylamine, or 2-aminopropane.

b.



–OH represents the hydroxyl functional group; cyclohexanol.

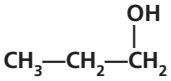
c.



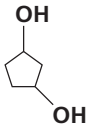
–O– represents an oxygen atom in a carbon chain; methylpropyl ether.

11. Draw the structure for each molecule.

a. 1-propanol



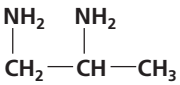
b. 1,3-cyclopentanediol



c. propyl ether

$CH_3–CH_2–CH_2–O–CH_2–CH_2–CH_3$

d. 1,2-propanediamine



12. Discuss the properties of alcohols, ethers, and amines, and name one use of each.

alcohols—moderately polar; can form hydrogen bonds with other molecules; higher boiling points than other alkanes of similar shape and size; example—ethanol; ethers—cannot form hydrogen bonds; lower boiling points and volatile; less soluble in water than alcohols; example—methyl ether; amines—some amines have volatile odors that humans find offensive; example—cyclohexylamine

13. Analyze Based on the molecular structures below, which compound would you expect to be more soluble in water? Explain your reasoning.

Ethanol (on the right) is more soluble than methyl ether. Because of their molecules' greater polarities, alcohols are usually more water-soluble than ethers.

Section 22.3 Carbonyl Compounds

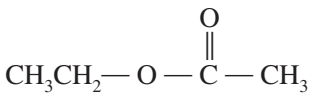
pages 796–801

Section 22.3 Assessment

page 801

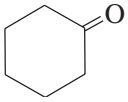
14. Classify each of the carbonyl compounds as one of the types of organic substances you have studied in this section.

a.



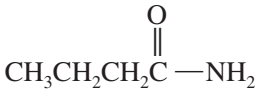
ester

b.



amide

c.



amine

d.

aldehyde

15. Describe the products of a condensation reaction between a carboxylic acid and an alcohol.

The products are an ester and water.

16. Determine The general formula for alkanes is C_nC_{2n+2}. Derive a general formula to represent an aldehyde, a ketone, and a carboxylic acid.

Aldehyde: $C_nH_{2n}O$; ketone: $C_nH_{2n}O$; carboxylic acid: $C_nH_{2n}O_2$

17. Infer why water-soluble organic compounds with carboxyl groups exhibit acidic properties in solutions, whereas similar compounds with aldehyde structures do not exhibit these properties.

The carboxyl group can readily ionize donating an H^+ ion. However, the hydrogen atom bonded to an aldehyde's carbonyl group does not readily ionize.

Section 22.4 Other Reactions of Organic Compounds

pages 802–808

Section 22.4 Assessment

page 808

18. Classify each reaction as substitution, elimination, addition, or condensation.

a. $CH_3CH{=}CHCH_2CH_3 + H_2 \rightarrow CH_3CH_2{-}CH_2CH_2CH_3$

addition

b. $CH_3CH_2CH_2\underset{\displaystyle OH}{\underset{|}{C}}HCH_3 \rightarrow CH_3CH_2CH{=}CHCH_3 + H_2O$

elimination

19. Identify the type of organic reaction that would best accomplish each conversion.

a. alkyl halide → alkene

elimination

b. alkene → alcohol

addition

c. alcohol + carboxylic acid → ester

condensation

d. alkene → alkyl dihalide

addition

20. Complete each equation by writing the condensed structural formula for the product that is most likely to form.

a. $CH_3CH{=}CHCH_2CH_3 + H_2 \rightarrow$

$CH_3CH_2CH_2CH_2CH_3$

b. $CH_3CH_2\underset{\displaystyle Cl}{\underset{|}{C}}HCH_2CH_3 + OH^- \rightarrow$

$CH_3CH_2CH(OH)CH_2CH_3$

21. Predicting Products Explain why the hydration reaction involving 1-butene might yield two distinct products, whereas the hydration of 2-butene yields only one product.

Hydrating 1-butene might yield 1-butanol and/or 2-butanol because hydroxyl groups might bond to carbons 1 and/or 2 of the 4-carbon chain. Hydrating 2-butene, however, yields only 2-butanol because the hydroxyl group must be on carbon 2.

Section 22.5 Polymers

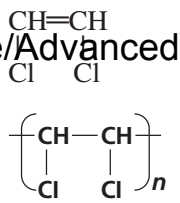
pages 809–814

Section 22.5 Assessment

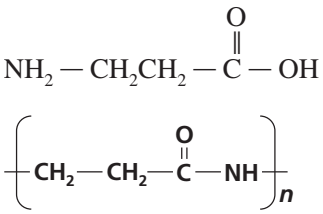
page 814

22. Draw the structure for the polymer that could be produced from each of the following monomers by the method stated.

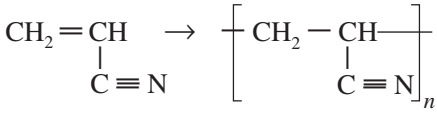
a. Addition



b. Condensation



23. Label the following polymerization reaction as *addition* or *condensation*. Explain your answer.

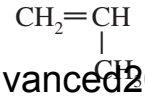


addition, because all of the atoms present in the monomer are retained in the monomer

24. Identify Synthetic polymers often replace stone, wood, metals, wool, and cotton in many applications. Identify some advantages and disadvantages of using synthetic materials instead of natural materials.

Synthetic materials often do not rot and decay like natural products, such as wood and cotton. Synthetic materials are easy to produce in desired shapes and sizes, such as synthetic stone. Synthetic materials usually do not rust or corrode like metals. Disadvantage: Synthetic structural products like plastic lumber are not as rigid and need more supports.

25. Predict the physical properties of the polymer that is made from the following monomer. Mention solubility in water, electrical conductivity, texture, and chemical reactivity. Do you think it will be thermoplastic or thermosetting? Give reasons for your predictions.



The polymer will have a waxy feel, low water solubility, low electric conductivity, and low reactivity. It will be thermoplastic. It is a long-chain alkane similar to polyethylene.

Chapter 22 Assessment

pages 818–821

Section 22.1

Mastering Concepts

26. What is a functional group?

A functional group is an atom or group of atoms in an organic molecule that always reacts in a certain way.

27. Describe and compare the structures of alkyl halides and aryl halides.

Alkyl halides have a halogen atom present on an aliphatic chain or ring of carbons, while aryl halides have a halogen atom directly bonded to a carbon on a benzene molecule or other aromatic ring.

28. What reactant would you use to convert methane to bromomethane?

bromine

29. Name the amines represented by each of the condensed formulas.

a. $CH_3(CH_2)_3CH_2NH_2$

1-aminopentane

b. $CH_3(CH_2)_5CH_2NH_2$

1-aminoheptane

c. $CH_3(CH_2)_2CH(NH_2)CH_3$

2-aminopentane

d. $CH_3(CH_2)_8CH_2NH_2$

1-aminodecane

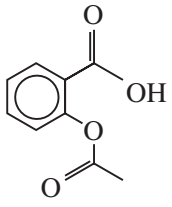
30. Explain why the boiling points of alkyl halides increase in order going down the column of halides in the periodic table, from fluorine through iodine.

This trend is primarily because the halogens from fluorine to iodine have increasing numbers of electrons that lie farther from the halogen nucleus. These electrons shift easily and form temporary dipoles. The dipoles attract each other and the energy needed to separate them increases. As a result, the boiling points of halogen-substituted alkanes increase as the size of the halogen atom increases.

Mastering Problems

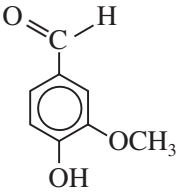
31. Circle and name each of the functional groups circled in the structures shown in **Figure 22.22.**

a.



carboxylic acid and ester

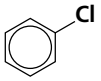
b.



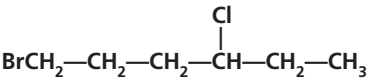
aldehyde, ether and alcohol

32. Draw structures for these alkyl and aryl halides.

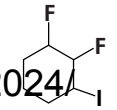
a. chlorobenzene



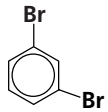
b. 1-bromo-4-chlorohexane



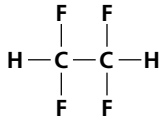
c. 1,2-difluoro-3-iodocyclohexane



d. 1,3-dibromobenzene

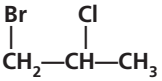


e. 1,1,2,2-tetrafluoroethane



33. For 1-bromo-2-chloropropane:

a. Draw the structure.



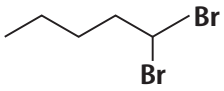
b. Does the compound have optical isomers?

Yes; one carbon is attached to four different atoms or groups.

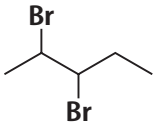
c. If the compound has optical isomers, identify the chiral carbon atom.

The middle carbon is chiral.

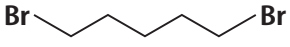
34. Draw and name all of the structural isomers possible for an alkyl halide with no branches and the molecular formula $C_5H_{10}Br_2$.



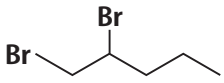
1,1-dibromopentane



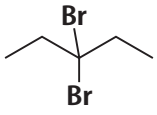
2,3-dibromopentane



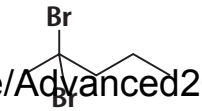
1,5-dibromopentane



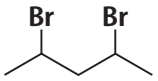
1,2-dibromopentane



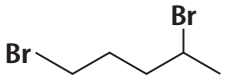
3,3-dibromopentane



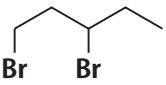
2,2-dibromopentane



2,4-dibromopentane



1,4-dibromopentane



1,3-dibromopentane

35. Name one structural isomer created by changing the position of one or more halogen atoms in each alkyl halide.

a. 2-chloropentane

1-chloropentane; 3-chloropentane

b. 1,1-difluropropane

1,2-difluoropropane; 1,3-difluoropropane; 2,2-difluoropropane

c. 1,3-dibromocyclopentane

1,2- or 1,1-dibromocyclopentane

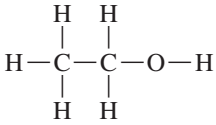
d. 1-bromo-2-chloroethane

1-bromo-1-chloroethane

Section 22.2

Mastering Concepts

36. How is the compound shown in **Figure 22.23** denatured? What is the name of the compound?



Ethanol is denatured by the addition of small amounts of toxic substances, which make it unsafe to drink.

37. Practical Applications Name one alcohol, amine, or ether that is used for each of the following purposes.

a. antiseptic

ethanol

b. solvent in paint strippers

methanol

c. antifreeze

ethylene glycol or propylene glycol

d. anesthetic

ethyl ether

e. dye production

aniline

38. Explain why an alcohol molecule will always have a higher solubility in water than an ether molecule having an identical molecular mass.

Alcohols are always polar due to the asymmetrical distribution of charge around the oxygen in the -OH group. Polarity of an ether depends on its overall geometry. Alcohols are generally more soluble than corresponding ethers in water, which is a polar solvent.

39. Explain why ethanol has a much higher boiling point than aminoethane, even though their molecular masses are nearly equal.

Because O—H bonds are more polar than N—H bonds, the hydrogen bonds that form between two ethanol molecules are stronger than those that form between two aminoethane molecules. Stronger intermolecular forces result in higher boiling points.

Mastering Problems

40. Name one ether that is a structural isomer of each alcohol.

a. 1-butanol

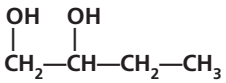
ethyl ether; methyl propyl ether

b. 2-hexanol

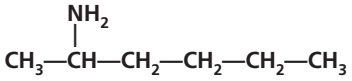
propyl ether; isopropyl ether; butyl ethyl ether; methyl pentyl ether

41. Draw structures for the following alcohol, amine, and ether molecules.

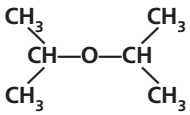
a. 1,2-butanediol



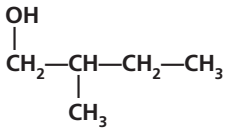
b. 5-aminohexane



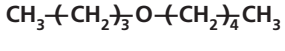
c. isopropyl ether



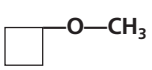
d. 2-methyl-1-butanol



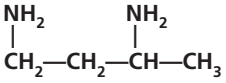
e. butyl pentyl ether



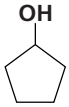
f. cyclobutyl methyl ether



g. 1,3-diaminobutane



h. cyclopentanol

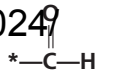


Section 22.3

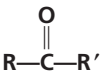
Mastering Concepts

42. Draw the general structure for each of the following classes of organic compounds.

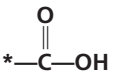
a. aldehyde



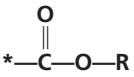
b. ketone



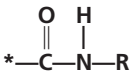
c. carboxylic acid



d. ester



e. amide



43. Common Uses Name an aldehyde, ketone, carboxylic acid, ester, or amide used for each of the following purposes.

a. preserving biological specimens

formaldehyde

b. solvent in fingernail polish

acetone

c. acid in vinegar

acetic acid

d. flavoring in foods and beverages

ethyl butanoate, 2-methylbutylacetate, pentyl pentanoate, or other ester

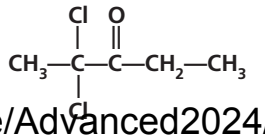
44. What type of reaction is used to produce aspirin from salicylic acid and acetic acid?

condensation

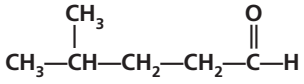
Mastering Problems

45. Draw structures for each of the following carbonyl compounds.

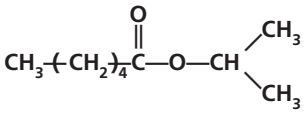
a. 2,2-dichloro-3-pentanone



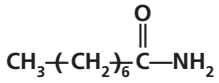
b. 4-methylpentanal



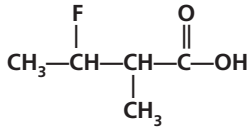
c. isopropyl hexanoate



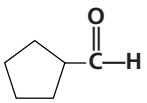
d. octanoamide



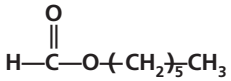
e. 3-fluoro-2-methylbutanoic acid



f. cyclopentanal

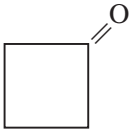


g. hexyl methanoate



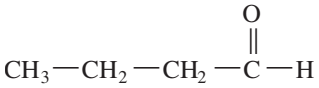
46. Name each of the following carbonyl compounds.

a.



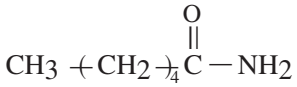
cyclobutanone

b.



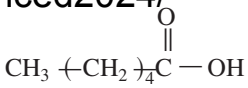
butanal

c.



hexanoamide

d.



hexanoic acid

Section 22.4

Mastering Concepts

47. Synthetic Organic Compounds What is the starting material for making most synthetic organic compounds?

fossil fuels such as petroleum or natural gas

48. Explain the importance of classifying reactions.

Because chemical reactions are so numerous, classifying them helps students and chemists better understand them, remember them, and predict the products of new reactions.

49. List the type of organic reaction needed to perform each of the following transformations.

a. alkene → alkane

addition

b. alkyl halide → alcohol

substitution

c. alkyl halide ⟶ alkene

elimination

d. amine + carboxylic acid ⟶ amide

condensation

e. alcohol ⟶ alkyl halide

substitution

f. alkene ⟶ alcohol

addition and hydration

Mastering Problems

50. Classify each of the following organic reactions as substitution, addition, oxidation-reduction elimination, or condensation.

a. 2-butene + hydrogen ⟶ butane

addition

b. propane + fluorine ⟶ 2-fluoropropane + hydrogen fluoride

substitution

c. 2-propanol ⟶ propene + water

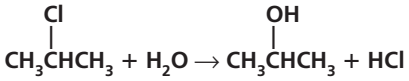
elimination

d. cyclobutene + water ⟶ cyclobutanol

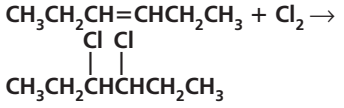
addition

51. Use structural formulas to write equations for the following reactions.

a. the substitution reaction between 2-chloropropane and water yielding 2-propanol and hydrogen chloride



b. the addition reaction between 3-hexene and chlorine yielding 3,4-dichlorohexane



52. What type of reaction converts an alcohol into each of the following types of compounds?

a. ester

condensation

b. alkyl halide

substitution

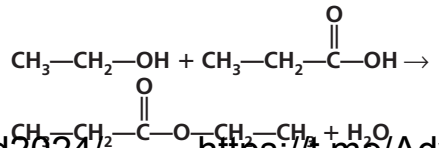
c. alkene

elimination

d. aldehyde

oxidation

53. Use structural formulas to write the equation for the condensation reaction between ethanol and propanoic acid.



Section 22.5

Mastering Concepts

54. Explain the difference between addition polymerization and condensation polymerization.

In addition polymerization, all the atoms in the monomers are retained in the polymer product. In condensation polymerization, monomers with at least two functional groups form the polymer, losing a small by-product such as water.

55. Which type of polymer is easier to recycle, thermosetting or thermoplastic? Explain your answer.

Thermoplastic polymers are easier to recycle because products made from them can be re-melted and molded repeatedly.

Mastering Problems

56. Manufacturing Polymers What monomers react to make each polymer?

a. polyethylene

ethene(C_2H_4)

b. polyvinyl chloride

chloroethene(CH_2CHCl)

c. polytetrafluoroethylene

tetrafluoroethene(C_2F_4)

57. Name the polymers made from the following monomers.

a. CH_3Cl

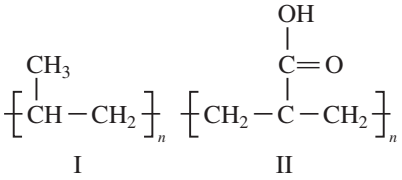
polyvinyl chloride

b. $CH_2{=}CCl_2$

polyvinylidene chloride (Saran)

58. Choose the polymer of each pair that you expect to have the higher water solubility.

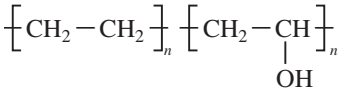
a.



I II

the second polymer

b.



the second polymer

59. Examine the structures of the following polymers. Decide whether each is made by addition or condensation polymerization.

a. nylon

condensation polymerization

b. polyacrylonitrile

addition polymerization

c. polyurethane

condensation polymerization

d. polypropylene

addition polymerization

60. Human Hormones Which halogen is found in hormones made by a normal human thyroid gland?

iodine

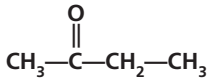
Mixed Review

61. Describe the properties of carboxylic acids.

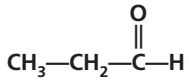
Carboxylic acids are weakly acidic, taste sour, and consist of polar molecules.

62. Draw structures of the following compounds.

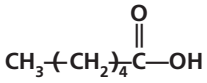
a. butanone



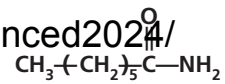
b. propanal



c. hexanoic acid



d. heptanoamide



63. Name the type of organic compound formed by each of the following reactions.

a. elimination from an alcohol

alkene

b. addition of hydrogen chloride to an alkene

alkyl halide

c. addition of water to an alkene

alcohol

d. substitution of a hydroxyl group for a halogen atom

alcohol

64. List two uses for each of the following polymers.

a. polypropylene
b. polyurethane
c. polytetrafluoroethylene
d. polyvinyl chloride

See Table 22.14 for possible answers

65. Draw structures of and supply names for the organic compounds produced by reacting ethene with each of the following substances.

a. water

CH_3CH_2OH, ethanol

b. hydrogen

CH_3CH_3, ethane

c. hydrogen chloride

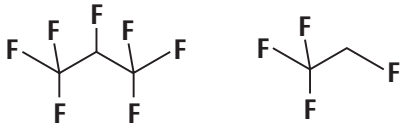
CH_3CH_2Cl, chloroethane

d. fluorine

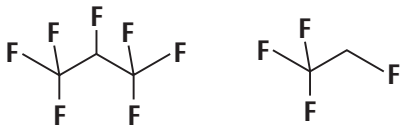
1,2-difluoroethane

66. Environmentally-Safe Propellants Hydrofluoroalkanes (HFAs) are replacing chlorofluorocarbons in hand-held asthma inhalers, because of CFC damage to the ozone layer. Draw the structures of the HFAs listed below.

a. 1,1,1,2,3,3,3-heptafluoropropane



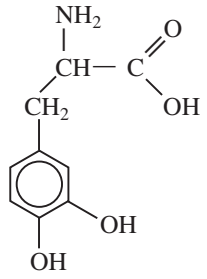
b. 1,1,1,2,-tetrafluoroethane



Think Critically

67. Interpret Scientific Illustrations List all the functional groups present in each of the following complex organic molecules.

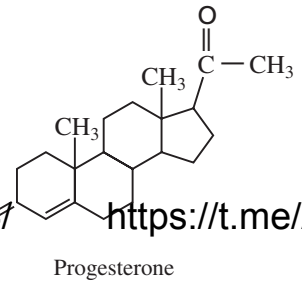
a.



Levadopa

carboxyl, amino, hydroxyl (2)

b.



Progesterone

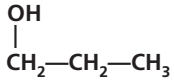
carbonyl (2), C═C

68. Evaluate Ethanoic acid (acetic acid) is very soluble in water. However, naturally occurring long-chain carboxylic acids, such as palmitic acid ($CH_3(CH_2)_{14}COOH$), are insoluble in water. Explain.

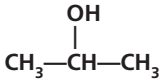
Ethanoic acid is soluble in water because its molecules are relatively small, form hydrogen bonds with water when unionized, and form ion-dipole attractions when ionized. Carboxylic acid molecules with much longer carbon chains are mostly nonpolar. These nonpolar molecules do not form strong bonds with water molecules, even though their carboxylic acid groups have a slight tendency to interact with water molecules.

69. Communicate Write structural formulas for all structural isomers of molecules having the following formulas. Name each isomer.

a. C_3H_8O



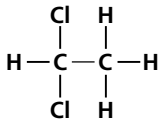
1-propanol



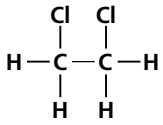
2-propanol

ethyl methyl ether

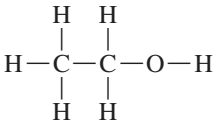
b. $C_2H_4Cl_2$



1,1-dichloroethane



1,2-dichloroethane

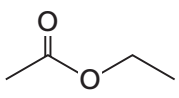


70. Interpret Scientific Illustrations Human cells require vitamin C to properly synthesize materials that make up connective tissue such as that found in ligaments. List the functional groups present in the Vitamin C molecule shown in **Figure 22.24.**

hydroxyl (4), cyclic alkene C=C, carbonyl, ether

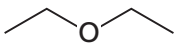
71. Identify Draw the structure of an example of an organic molecule that has four carbons and falls into each of the compound types listed.

a. ester



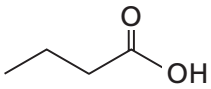
ethyl ethanoate
(ethyl acetate)

b. aldehyde



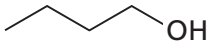
diethyl ether

c. ether



butanal
(butyraldehyde)

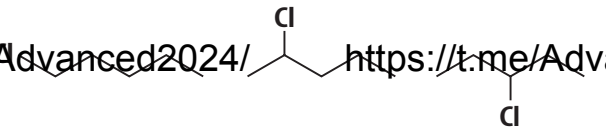
d. alcohol



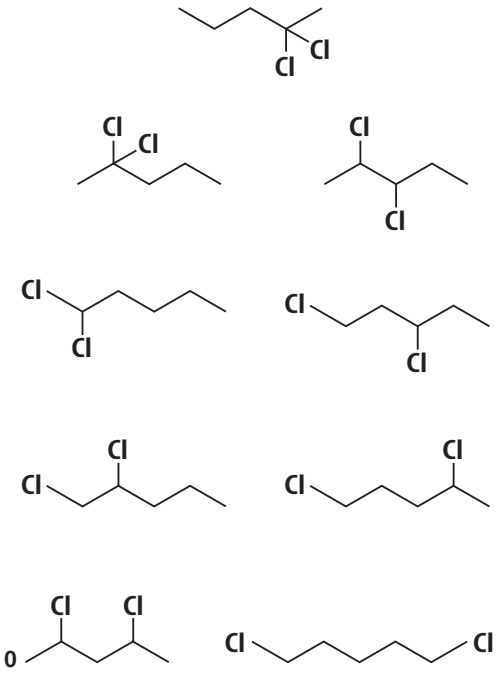
1–butanol

72. Predict A monohalogenation reaction describes a substitution reaction in which a single hydrogen atom is replaced by a halogen. A dihalogenation reaction is a reaction in which two hydrogen atoms are replaced by two halogen atoms.

a. Draw the structures of all the possible monohalogenation products that can form when pentane reacts with Cl_2.



b. Draw the structures of all the possible dihalogenation products that can form when pentane reacts with Cl_2.



Alcohol Solubility in Water (mol/100 g H2O)		
Name	**Alcohol**	**Solubility**
Methanol	CH_3OH	infinite
Ethanol	C_2H_5OH	infinite
Propanol	C_3H_7OH	infinite
Butanol	C_4H_9OH	0.11
Pentanol	$C_5H_{11}OH$	0.030
Hexanol	$C_6H_{13}OH$	0.0058
Heptanol	$C_7H_{15}OH$	0.0008

73. Evaluate Examine **Table 22.15** comparing some alcohols and their solubility in water. Use the table to answer the following questions.

a. What type of bond forms between the −OH group of alcohols and water?

hydrogen bonds

b. State a relationship between water solubility and alcohol size from the data in the table.

As the size of an alcohol increases, its water solubility decreases.

c. Provide an explanation for the relationship you stated in Part b.

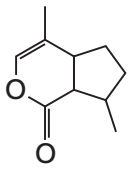
As the number of carbons in an alcohol increases, the size of its nonpolar portion increases while its polar portion remains the same. As a result, its solubility in the polar molecule water decreases.

74. Recognize Most useful organic molecules are made from raw materials using several steps. This is called a multistep synthesis pathway. Label the types of reaction or process taking place in each step of the multistep synthesis pathway below.

petroleum → ethane → chloroethane → ethene → ethanol → ethanoic (acetic) acid

fractional distillation; substitution using UV light/Cl_2; elimination of HCl; addition of H_2O (hydration); oxidation

Challenge Problem

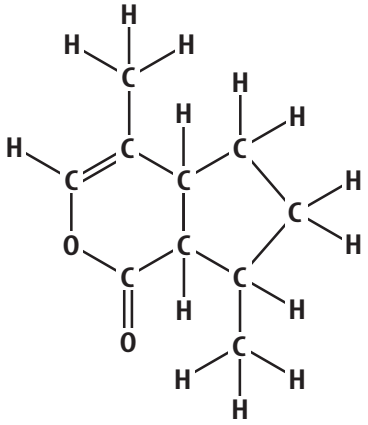


75. Animal Pheromones Catnip contains an organic chemical known as *nepetalactone*, shown in **Figure 22.25,** that is thought to mimic feline sex pheromones. Cats will rub in it, roll over it, paw at it, chew it, lick it, leap about, then purr loudly, growl, and meow for several minutes before losing interest. It takes up to two hours for the cat to "reset" and then have the same response to the catnip.

a. What type of organic compound is nepetalactone?

ester

b. Draw the structural formula for nepetalactone on a sheet of paper and then draw in all the missing hydrogen atoms. Remember that carbon atoms must have four bonds to be stable.



c. Write the molecular formula for nepetalactone.

$C_{11}H_{14}O_2$

Cumulative Review

76. Explain why the concentration of ozone over Antarctica decreases at about the same time every year. *(Chapter 1)*

The same weather (temperature) patterns occur at about the same time every year.

77. Why do the following characteristics apply to transition metals? *(Chapter 6)*

a. Ions vary in charge.

Transition metals can lose ns^2 outer electrons forming 2+ ions. They also can lose inner d electrons and form ions of 3+ or higher.

b. Many of their solids are colored.

Electrons in d orbitals can absorb visible light of specific wavelengths as the atom moves to an excited state.

c. Many are hard solids.

Hardness is a property determined by the number of unpaired d electrons: the more unpaired d electrons, the harder the solid.

78. Determine the number of atoms in each of the following. *(Chapter 10)*

a. 56.1 g Al

$$\frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} \times \frac{1 \text{ mol Al}}{26.982 \text{ g Al}} \times 56.1 \text{ g Al}$$
$$= 1.25 \times 10^{24} \text{ atoms}$$

b. 2 moles C

$$\frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} \times 2 \text{ mol}$$
$$= 1.20 \times 10^{24} \text{ atoms}$$

79. What is a rate-determining step? *(Chapter 16)*

The rate-determining step is the slowest of the elementary reactions that make up a complex reaction.

80. According to Le Châtelier's principle, how would increasing the volume of the reaction vessel affect the equilibrium $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$? *(Chapter 17)*

The equilibrium will shift to the left because it has more moles of gas than the right.

81. Compare and contrast saturated and unsaturated hydrocarbons. *(Chapter 21)*

A saturated hydrocarbon contains only single bonds. An unsaturated hydrocarbon contains at least one double or triple bond between carbon atoms.

Additional Assessment

Writing in Chemistry

82. Historical Perspective Write a short story describing how your life would differ if you lived in the 1800s, before the development of synthetic polymers.

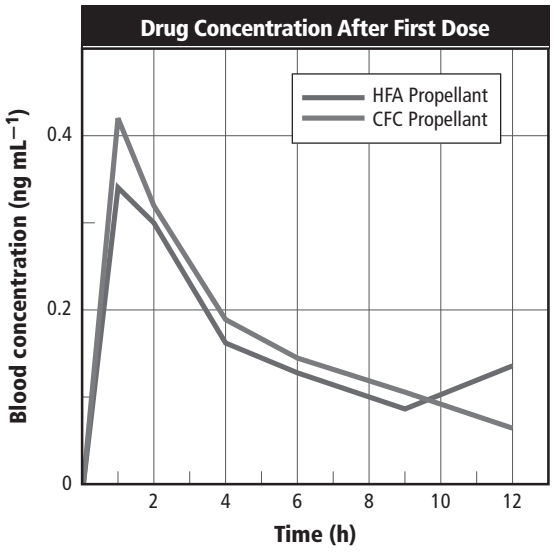
Student answers should include discussing what alternatives they would have to use in place of the many synthetic polymers in everyday use today, such as plastic bags, rubber bands, nylon and polyester fabrics, and plastic bottles.

Document-Based Questions

Pharmaceutical Propellants Many inhaled medications used to treat asthma contained chlorofluorocarbon (CFC). However, the Montreal Protocol called for a ban of CFCs as a propellant in pharmaceutical products by 2008. Two hydrofluoroalkanes (HFAs) appear to be effective in delivering asthma medications to the lungs. However, the medications need to be customized when using HFA propellants.

Figure 22.6 *shows the concentration after one dose of the drug beclomethasone in the blood of volunteers using a CFC or an HFA propellant in the inhaler.*

Data obtained from: Anderson, P.J. 2006. *Chest: The Cardiopulmonary and Critical Care Journal. 120:89–93*



83. After one dose of the drug beclomethasone was given, which propellant resulted in the highest concentration of medication in the blood, HFA or CFC?

HFA

84. When does the drug reach its peak concentration?

at about 1 hour

85. Only one-half the amount of medication is needed with the HFA propellant when compared to the CFC propellant to achieve a similar blood-concentration level. Infer the advantages of using a lower dose of medication to get similar results.

If the patient uses 1/2 the dosage, the patient is at a lower risk of experiencing side effects from the drug. Also, the drug will cost less for the patient!

Standardized Test Practice

pages 822–823

Multiple Choice

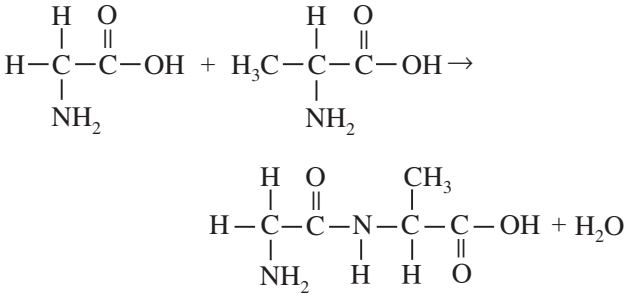
1. What are the products of this reaction?

$CH_3CH_2CH_2Br + NH_3 \rightarrow ?$

a. $CH_3CH_2CH_2NH_2Br$ and H_2
b. $CH_3CH_2CH_2NH_3$ and Br_2
c. $CH_3CH_2CH_2NH_2$ and HBr
d. $CH_3CH_2CH_3$ and NH_2Br

c

2. What kind of reaction is this?



a. substitution
b. condensation
c. addition
d. elimination

b

3. What are the oxidation numbers of the elements in $CuSO_4$?

a. Cu = +2, S = +6, O = −2
b. Cu = +3, S = +5, O = −2
c. Cu = +2, S = +2, O = −1
d. Cu = +2, S = +6, O = −2

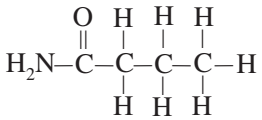
a

4. The corrosion, or rusting, of iron is an example of a naturally occurring voltaic cell. To prevent corrosion, sacrificial anodes are sometimes attached to rust-susceptible iron. Sacrificial anodes must

a. be more likely to be reduced than iron.
b. have a higher reduction potential than iron.
c. be more porous and abraded than iron.
d. lose electrons more easily than iron.

d

5. What type of compound does this molecule represent?



a. amine
b. amide
c. ester
d. ether

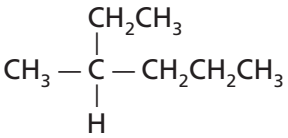
b

6. Diprotic succinic acid ($H_2C_4H_4O_4$) is an important part of the process that converts glucose to energy in the human body. What is the K_a expression for the second ionization of succinic acid?

a. $K_a = [H_3O^+][HC_4H_4O_4^-] / [H_2C_4H_4O_4]$
b. $K_a = [H_3O^+][HC_4H_4O_4^{2-}] / [HC_4H_4O_4^-]$
c. $K_a = [H_2C_4H_4O_4] / [H_3O^+][HC_4H_4O_4^-]$
d. $K_a = [H_2C_4H_4O_4] / [H_3O^+][C_4H_4O_4^{2-}]$

b

Use the figure below to answer Question 7.



7. Which is the correct name for this compound?

a. 3-methyl hexane
b. 2-ethyl pentane
c. 2-propyl butane
d. 3-ethyl-3-methyl butane

a

8. A strip of metal X is immersed in a 1*M* solution of X^+ ions. When this half-cell is connected to a standard hydrogen electrode, a voltmeter reads a positive reduction potential. Which is true of the X electrode?

a. It accepts electrons more readily than H^+ ions.
b. It is undergoing oxidation.
c. It is adding positive X+ ions to its solution.
d. It acts as the anode in the cell.

a

9. What is the mass of one molecule of barium hexafluorosilicate ($BaSiF_6$)?

a. 4.64×10^{-22} g
b. 1.68×10^{26} g
c. 2.16×10^{21} g
d. 6.02×10^{-23} g

a

$$1 \text{ molecule} \times \frac{1 \text{ mol } BaSiF_6}{6.02 \times 10^{23} \text{ molecules}} \times \frac{279.4 \text{ g } BaSiF_6}{1 \text{ mol } BaSiF_6} = 4.64 \times 10^{-22} \text{ g } BaSiF_6$$

10. Which type of compound accepts H+ ions?

a. an Arrhenius acid
b. an Arrhenius base
c. a Brønsted-Lowry acid
d. a Brønsted-Lowry base

d

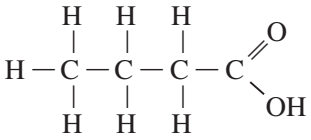
11. Which substituted hydrocarbon has the general formula R–OH?

a. alcohol
b. amine
c. ketone
d. carboxylic acid

a

Short Answer

Use the figure below to answer Questions 12 and 13.



12. What is the functional group present in this compound?

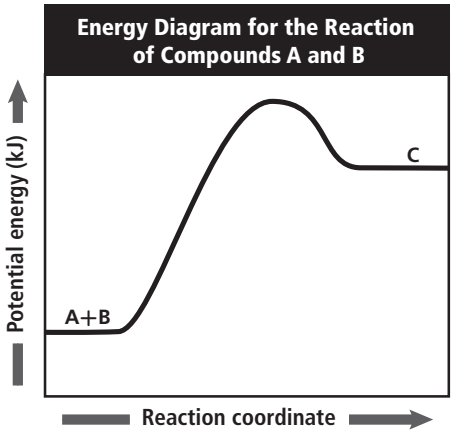
carboxyl group

13. Give the name for this compound.

butanoic acid

Extended Resonse

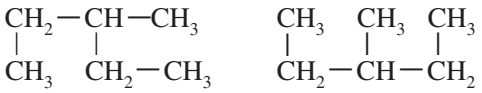
Use the graph below to answer Question 14.



14. Discuss the reaction that results in the shape of the energy graph shown.

This is an endothermic reaction, where energy must be added. This is shown by the energy level of the products being higher than the energy level of the reactants. The rise in the middle of the graph is due to the activation energy required to get the particles in the reaction into the proper orientation to react.

Use the figure below to answer Question 15.



15. The two structures above both have the molecular formula C_6H_{14}. Are they isomers of one another? Explain how you can tell.

These are not isomers. Isomers have the same molecular formula but different geometrical forms. Although these two structures appear different, they both have the IUPAC name 3-methyl pentane. They are the same compound but viewed in different orientations.

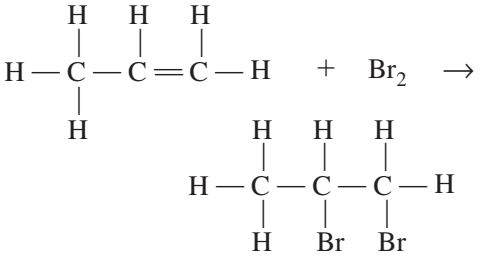
SAT Subject Test: Chemistry

16. To electroplate an iron fork with silver,

a. the silver electrode must have more mass than the fork.
b. the iron fork must act as the anode in the cell.
c. electric current must be applied to the iron fork.
d. iron ions must be present in the cell solution.
e. the electric current must be pulsed.

c

17. Which type of reaction is shown below?



a. condensation
b. dehydration
c. polymerization
d. halogenation
e. hydration

d

Use the table below to answer Question 18.

Experimental Data for A + B → C

Time	[A]*M*	[B]*M*	[C]*M*
0.00 sec	0.35	0.50	0.00
5.00 sec	0.15	0.30	0.40

18. Which is the rate of this reaction in terms of moles of product per second?

a. 0.40 mol/s
b. 0.85 mol/s
c. 0.08 mol/s
d. 0.17 mol/s
e. 0.93 mol/s

c

$$\text{average reaction rate} = \frac{\Delta[\text{product}]}{\Delta t} = \frac{0.40 - 0.00 \text{ mol}}{\text{L}/5.00\ s - 0.00\ s} = 0.08 \text{ mol/L.s} = 0.08 \text{ M/s}$$