3.1 Identify the functional groups in each of the following molecules:

(a)  \[
\begin{array}{c}
\text{C} \\
\text{O} \\
\text{NH}_{2}
\end{array}
\]
(b)  \[
\begin{array}{c}
\text{N} \\
\text{C} \\
\text{OH}
\end{array}
\]
(c)  \[
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{OCH}_{3}
\end{array}
\]
(d)  \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{CH}_{2} \text{CH}_{2} \text{OH}
\end{array}
\]

Solutions:

a. Amide, double bond
b. Amine, carboxylic acid
c. Double bond, ketone, ester
d. Aromatic ring, double bond, alcohol

3.2 Propose structures for simple molecules that contain the following functional groups:

(a) Alcohol  (b) Aromatic ring  (c) Carboxylic acid  
(d) Amine  (e) both ketone and amine  (f) two double bonds

Solutions:

(a).  \[
\begin{array}{c}
\text{H}_{3}\text{C} \text{—OH}
\end{array}
\]
(b).  \[
\begin{array}{c}
\text{CH}_{3}
\end{array}
\]
(c).  \[
\begin{array}{c}
\text{H}_{3}\text{C} \text{—OH}
\end{array}
\]
(d).  \[
\begin{array}{c}
\text{H}_{3}\text{C} \text{—NH}_{2}
\end{array}
\]
(e).  \[
\begin{array}{c}
\text{CH}_{3}\text{CH}_{2}\text{COCH}_{2}\text{CH}_{2}\text{NH}_{2}
\end{array}
\]
(f).  \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{CH}_{2}
\end{array}
\]

3.3 Identify the functional groups in the following model of arecoline, a veterinary drug used to control worms in animals. Convert the drawing into a line-bond structure and a molecular formula.
Solution:
Line-bond structure:
Molecular formula: C₈H₁₃NO₂

3.4 Draw structures of the five isomers of C₆H₁₄.
Solution:

3.5 Propose structures that meet the following descriptions:
(a) Two isomeric esters with the formula C₅H₁₀O₂
(b) Two isomeric nitriles with the formula C₄H₇N
Solution:

(a):

(b):
3.6 How many isomers are there with the following descriptions?
(a) Alcohols with the formula C₃H₈O
(b) Bromoalkanes with the formula C₄H₉Br
Solution:

(a): 2
(b): 4

3.7 Draw the eight 5-carbon alkyl groups (pentylic isomers).
Solution

3.8 Identify the carbon atoms in the following molecules as primary, secondary, tertiary, or quaternary:
Solution:
(a)
(b)
(c)
3.9 Identify the hydrogen atoms on the compounds shown in Problem 3.8 as primary, secondary, or tertiary.

Solution: The hydrogen in red is primary hydrogens; in blue is secondary hydrogens; in green is tertiary hydrogens

(a) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \]

(b) \[ \text{CH}_3\text{CCHCH}_3 \]

(c) \[ \text{CH}_3\text{CHCH}_2\text{CH}_3 \]

3.10 Draw structures of alkanes that meet the following descriptions:

(a) An alkane with two tertiary carbons
(b) An alkane that contains an isopropyl group
(c) an alkane that has one quaternary and one secondary carbon

Solution: (a) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \]

(b) \[ \text{CH}_3\text{CHCH}_2\text{CH}_3 \]

(c) \[ \text{CH}_3\text{CCHCH}_3 \]

3.11 Give IUPAC names for the following compounds:

(a) The three isomers of \( \text{C}_5\text{H}_{12} \)

(b) \[ \text{H}_3\text{CH}_2\text{C} = \text{CH} = \text{CHCH}_3 \]

(c) \[ (\text{H}_3\text{C})_2\text{CHCH}_2\text{C} = \text{CH} = \text{CH}_3 \]

(d) \[ (\text{H}_3\text{C})_3\text{CH}_2\text{CH}_2\text{C} = \text{CH} = \text{CH}_2\text{CH}_3 \]
3.12 Draw structures corresponding to the following IUPAC names:
(a) 3,4-Dimethylnonane
(b) 3-Ethyl-4,4-dimethylheptane
(c) 2,2-Dimethyl-4-propyloctane
(d) 2,2,4-Trimethylpentane

Solution:

(a) \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

(b) \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

(c) \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

(d) \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

3.13 Name the eight 5-carbon alkyl groups you drew in problem 3.7.

(3.7 Draw the eight 5-carbon alkyl groups.)

Solution:
3.14 Give the IUPAC name for the following hydrocarbon, and convert the drawing into a skeletal structure.

Solution:

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

3,3,4,5-Tetramethyl-heptane

3.15: Give the names of the following cycloalkanes.

Solution:
3.16: Draw the structure.
Solution:

(a) 1,4-Dimethylocyclohexane

(b) 1-methyl-3-propylcyclopentane

(c) 3-cyclobutylpentane

(d) 1-Bromo-4-ethylcyclodecane

(e) 1-Isopropyl-3-methylocyclohexane

(f) 1-Bromo-4-Isopropyl-3-methylocycloheptane
3.17 Name the following cycloalkane:

Solution: 3-Ethyl-1,1-dimethylcyclopentane

3.18 Name the following substances, including the cis- or trans- prefix:

Solution: trans-1-Chloro-4-methylcyclohexane
Solution: cis-1-Ethyl-3-methylcycloheptane

3.19: Draw the structures of the following molecules:
(a) trans-1-bromo-3-methylcyclohexane        (b) cis-1,2-dimethylcyclobutane
(c) trans-1-tert-butyl-2-ethylcyclohexane.

Solution:

(a) \[
\begin{array}{c}
\text{Br} \\
\text{H} \\
\text{H} \\
\text{CH}_3 \\
\text{H}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{H}_3\text{C} \\
\text{CH}_3 \\
\text{H} \\
\text{H}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{3-tert-butyl} \\
\text{2-ethyl}
\end{array}
\]

3.20: Name the following substance, including the cis- or trans- prefix (red-brown=Br).

Solution: (a) cis-1,2-dimethylcyclopentane.
(b) cis-1-bromo-3-methylcyclobutane.

3.21 Identify the functional groups in the following substances, and convert each drawing into a molecular formula (red=O, blue=N):

Solution: (a) The functional groups:
\[
\begin{array}{c}
\text{C} \\
\text{O} \\
\text{OH}
\end{array}
\]
The molecular formula: \(C_9H_{11}NO_2\)

(b) The functional groups:
\[
\begin{array}{c}
\text{H} \\
\text{N} \\
\text{C} \\
\text{O} \\
\text{N}
\end{array}
\]
The molecular formula: \(C_{14}H_{22}N_2O\)

3.22 Give IUPAC names for the following hydrocarbons, and convert each drawing into a skeletal structure (yellow-green=Cl):

Solution: (a) Name: 3,3,5-Trimethylheptane

The skeletal structure:

(b) Name: 1-Ethyl-3-methylcyclopropane

The skeletal structure:

(c) Name: 2,2,4-Trimethylpropane
The skeletal structure:

(d) Name: 1-Chloro-3-methylcyclohexane

The skeletal structure:

3.23 The following cyclohexane derivative has three substitutions-red, green, and blue. Identify each pair of relationships (red-green, red-blue, and blue-green), as cis or trans.

Solution: red-blue: trans.
red-green: trans.
blue-green: cis.

3.24 Locate and identify the functional groups in the following molecules:

(a) \( \text{CH}_2\text{OH} \) \( \text{NHCH}_3 \)
(b) \( \text{O} \)
(c) \( \text{NH} \) \( \text{C} \) \( \text{O} \) \( \text{CH}_3 \)
(d) \( \text{CH}_3\text{CHCOH} \) \( \text{NH}_2 \)
(e) \( \text{O} \)
(f) \( \text{Cl} \) \( \text{O} \)

Solution: (a)
3.25 Draw structures that meet the following descriptions (there are many possibilities):

(a) Three isomers with the formula C₈H₁₈

Solution:

(b) Two isomers with the formula C₄H₈O₂

Solution:
3.26 Draw structures of the nine isomers of $\text{C}_7\text{H}_{16}$
Solution: \[\text{H}_3\text{C} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_3 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]
\[\text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3 \quad \text{CH} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3\]

3.27 In each of the following sets, which structures represent the same compound and which represent different compounds?
(a) \[\text{CH}_3\text{CH(\text{Br})CHCH}_3 \quad (\text{CH}_3)_2\text{CHCH(\text{Br})CH}_3 \quad \text{CH}_2\text{CHCHCH}_3\]
Solution: They represent the same compound 2-Bromo-3-methyl-butane.
(b)
**Solution:** The first and the second represent the same compound Benzene-1, 2-diol. The third one represents different compound Benzene-1, 3-diol.

![Chemical structures](image)

**Solution:** The second and the third represent the same compound 2,4-Dimethyl-hexan-1-ol. The first one represents different compound 2-Ethyl-4-methyl-pentan-1-ol.

3.28 There are seven constitutional isomers with the formula C₄H₁₀O. Draw as many as you can.

**Solution:**

![Chemical structures](image)

3.29 Propose structure that meet the following descriptions:

(a). A ketone with five carbons
(b). A four-carbon amide
(c). A five-carbon ester
(d). An aromatic aldehyde
(e). A keto ester
(f). An amino alcohol

**Solution:**

![Chemical structures](image)
3.30 Propose structure for the following:
(a). A ketone, C₄H₈O
(b). A nitrile, C₅H₉N
(c). A dialdehyde, C₄H₆O₂
(d). A bromoalkene, C₆H₁₁Br
(e). An alkane, C₆H₁₄
(f). A cycloalkane, C₆H₁₂
(g). A diene (dialkene), C₅H₈
(h). A keto alkene, C₅H₈O

Solution:
(a).

(b).

(c).

(d).

(e).

(f).

(g).

(h).

3.31 Draw as many compounds as you can that fit the following description:
(a) Alcohols with formula C₄H₁₀O

(b) Amines with formula C₅H₁₃N
(c) Ketones with formula C₅H₁₀O

(d) Aldehydes with formula C₄H₉O

(e) Esters with formula C₄H₈O₂
3.32 Draw compounds that contain the following:
(a) A primary alcohol
\[ \text{CH}_3\text{OH} \]
(b) A tertiary nitrile
\[ \begin{array}{c}
\text{H} \\
\text{H}_3\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{H}_3 \\
\text{N} \\
\end{array} \]
(c) A secondary bromoalkane
\[ \text{Br} \]
(d) Both primary and secondary alcohols
\[ \begin{array}{c}
\text{OH} \\
\text{OH} \\
\end{array} \]
(e) An isopropyl group
\[ \text{CH}_3\text{CH}_2\text{CH}_3 \]
(f) A quaternary carbon
\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \]

3.33 Draw and name all monobromo derivations of pentane, \( \text{C}_5\text{H}_{10}\text{Br} \).
Solution:
\[ \begin{array}{c}
1\text{-bromopentane} \\
2\text{-bromopentane} \\
3\text{-bromopentane} \\
\end{array} \]

3.34 Draw and name all monochloro derivations of 2, 5-dimethylhexane, \( \text{C}_8\text{H}_{17}\text{Cl} \).
Solution:
3.35 Predict the hybridization of the carbon atom in each of the following functional groups:
(a) Ketone  (b) Nitrile  (c) Carboxylic acid
Solution: (a) sp²  (b) sp  (c) sp²

3.36 What is the molecular formula of each of the following condensed structures

Solution: (a) C₈H₁₆  (b) C₁₀H₁₆  (c) C₁₃H₁₆O

3.37 Draw the structure of a constitutional isomer for each of the molecules shown in Problem 3.36.
Solution:

(a) C₈H₁₆  (b) C₁₀H₁₆  (c) C₁₃H₁₆O

3.38 Draw the structures of the following molecules:
(a) Biacetyl, C₄H₆O₂, a substance with the aroma of butter; it contains no rings or carbon-carbon multiple bonds.
Solution: H₃C—C—O—O—CH₃
(b) Ethylenimine, C₂H₅N, a substance used in the synthesis of melamine polymers; it contains no multiple bonds.
Solution: H₂C—N—CH₂
(c) Glycerol, C₃H₈O₃, a substance used in cosmetics; it has an –OH group on each carbon.
Solution: OH   OH   OH
**3.39** Draw structures for the following:

(a) 2-Methylheptane

(b) 4-Ethyl-2,2-dimethylhexane

(c) 4-Ethyl-3,4-dimethyloctane

(d) 2,4,4-Trimethylheptane

(e) 3,3-Diethyl-2,5-dimethylnonane

(f) 4-Isopropyl-3-methylheptane

**3.40** Draw a compound that:

(a) Has only primary and tertiary carbons

(b) Has no primary carbons

(c) Has four secondary carbons

**Solution:**

(a)  

(b)  

(c)  

**3.41** Draw a compound that:

(a) Has no primary hydrogens. (b) Has only primary and tertiary hydrogens.

**Solution:**

(a)  

(b)  

**3.42** For each of the following compounds, draw an isomer with the same functional groups:
3.43 Draw structures for the following compounds:
(a) trans-1,3-Dibromocyclopentane
(b) cis-1,4-Diethylcyclohexane
(c) trans-1-Isopropyl-3-methylcycloheptane
(d) Dicyclohexylmethane
Solution:

(a) trans-1,3-Dibromocyclopentane

(b) cis-1,4-Diethylcyclohexane

(c) trans-1-Isopropyl-3-methylcycloheptane

(d) Dicyclohexylmethane
3.44 Identify the kinds of carbons (1′, 2′, 3′, or 4′) in the following molecules:

Solution:

a) the carbons which are not identified are all 1′

b) 

c) 

d) 

e) others are all 2′
3.45 Give IUPAC names for the following compounds.

(a) 2-methylpentane
(b) 2,2-dimethylbutane
(c) 2,3,3-trimethylhexane
(d) 2-methyl-5-ethylheptane
(e) 2-ethyl-2,4-dimethylheptane
(f) 2,2,3,3-tetramethylhexane
(g) 5-ethyl-3,5-dimethyloctane

3.46 Name the five isomers of \( \text{C}_6\text{H}_{14} \).

SOLUTION:
- hexane
- 2-methylpentane
- 3-methylpentane
- 2,2-dimethylbutane
- 2,3-dimethylbutane

3.47 Explain why each of the following name is incorrect:
(a) 2,2-Dimethyl-6-ethylheptane
(b) 4-Ethyl-5,5-dimethylpentane
(c) 3-Ethyl-4,4-dimethylhexane
(d) 5,5,6-Trimethyloctane
(e) 2-Isopropyl-4-methylheptane
(f) cis-1,5-Dimethylcyclohexane

Solution:
(a) The longest chain has 8 carbons, so the correct name should be 2,2,7-trimethyl-octane.
(b) A pentane can’t have a substituent at the 5th carbon, so the correct name should be
   3-ethyl-2-methylhaxane.
(c) The substituents should be cited in alphabetical order, so the correct name should be
   4,4-Dimehy-3-ethylhexane.
(d) We should begin at the end nearer the first branch point when number the carbons, so the correct
   name should be 3,4,4-Trimethyloctane.
(e) We should choose the chain with the larger number of branch points as the parent, so the correct
   name should be 2,3,5-trimethylhexane.
(f) The second substituent should has as low a number as possible, so the correct name should be
   cis-1,2-dimethylcyclohexane.

3.48 Propose structures and give IUPAC names for the following:
(a) A dimethylecyclooctane
(b) A diethyldimethylhexane
(c) A cyclic alkane with three methyl groups
(d) A (3-methylbutyl)-substituented alkane

Solution:

(a) cis-1,2dimethylcyclooctane

(b) 1,2-diethyl-3,4-dimethylhexane
3.49 Give IUPAC names for the following compounds:

(a) methylcycloheptane

(b) cis-1,3-dimethylcyclopentane

(c) trans-1,2-dimethylcyclohexane

(d) trans-1-i-propyl-2-methylcyclobutane
Glucose has the following structure. Identify each pair of relationships among the —OH groups as cis or trans.

Solution: red-blue: trans
red-green: cis
blue-green: trans
blue-black: cis
green-black: trans

Draw 1,3,5-trimethylcyclohexane using a hexagon to represent the ring. How many cis-trans stereoisomers are possible?

Solution:
The structure of 1,3,5-trimethylcyclohexane as follow:

And two cis-trans stereoisomers are possible.

Tell whether the following pairs of compounds are identical, constitutional isomers or stereoisomers:

(a) Cis-1, 3-dibromocyclohexane and trans-1, 4-dibromocyclohexane
(b) 2,3-dimethylhexane and 2,5,5-trimethylpentane
(c) [Diagram]

Solution:
(a) Constitutional isomers
(b) Constitutional isomers
(c) Identical
   a) Draw two constitutional isomers of cis-1,2-dibromocyclopentane.

Solution:
b) Draw a stereoisomer of trans-1,3-dimethylcyclobutane.
Solution:

3.53 Draw two constitutional isomers of cis-1,2-dibromocyclopentane.
Solution:

3.54 Draw a stereoisomer of trans-1,3-dimethylcyclobutane.
Solution:

3.55 There are four cis-trans isomers of menthol, including the one shown. Draw the other three.
Answer:

3.56 Malic acid, C₄H₆O₅, has been isolated from apples. Since this compound reacts with 2 molar equivalents of base, it is a dicarboxylic acid.
   (a) Draw at least five possible structures.
   (b) If malic acid is a secondary alcohol, what is its structure?
Answer:
3.57 Cyclopropane was first prepared by reaction of 1,3-dibromopropane with sodium metal. Formulate the cyclopropane-forming reaction and then predict the product of the following reaction. What geometry do you expect for the product? (Try building a molecular model.)

\[
\begin{align*}
\text{BrH}_2\text{C} & \quad \text{C} \quad \text{CH}_2\text{Br} \\
\text{CH}_2\text{Br} & \quad \rightarrow \quad 4\text{Na} \quad ?
\end{align*}
\]

Solution:
The product is:

3.58 Formaldehyde, \( \text{H}_2\text{C} \equiv \text{O} \) is known to all biologists because of its usefulness as a tissue preservative. When pure, formaldehyde trimerizes to give trioxane, \( \text{C}_3\text{H}_6\text{O}_3 \), which, surprisingly enough, has no carbonyl groups. Only one monobromo derivative \( (\text{C}_3\text{H}_5\text{BrO}_3) \) of trioxane is possible. Propose a structure for trioxane.

Solution:

3.59 Draw the five cycloalkanes with the formula \( \text{C}_5\text{H}_{10} \)

Solution:
3.60 There are two different substance named trans-1,2-dimethylcyclopentane. Make molecular models, and see if you can find the relationship between them.

Solutions:
They are enantiomers.

3.61 Cyclohexane has a pucked shape like a lounge chair rather than a flat shape. Why? (See section 4.8 and 4.9)

Solution:
First the C-C-C angels of Cyclohexane can reach the strain-free tetrahedral value, second in a newman projection, the chair Cyclohexane has no torsional strain, and all neighboring C-H bonds are staggered. The two reasons result the chair form lower energy and more stable.