Summer Review Packet for AP Chemistry

Targets:

1. To review and know the IUPAC naming system for inorganic compounds. (Practice Naming Worksheet)
2. To review and know the common polyatomic ions-names, formulas, and charges.
3. To review and know the solubility rules.
4. To review and know the principles of significant figures, to recognize how many sig figs are in a given number, and how to compute with sig figs.
5. To review stoichiometry calculations.
6. To understand the covalent bonding that takes place in hydrocarbons.
7. To know the naming system for alkanes, alkenes and alkynes.
8. To know properties of alkanes, alkenes and alkynes.
9. To recognize the ratio of C atoms to H atoms in a compound and how to categorize the compounds as alkanes, alkenes and alkynes.
10. To be able to draw and name the structural isomers of C_6H_{10} , C_6H_{12}, and C_6H_{14}.
11. To recognize common functional groups such as alcohols, ethers, carboxylic acids, etc.

Try the following websites for extra practice on organic naming and functional groups:

1. http://www.chemguide.co.uk/basicorg/conventions/names.html
2. http://www.chemhelper.com/practicetests.html
3. http://www.visionlearning.com/library/module_viewer.php?mid=60
4. www.youtube.com : Introduction to Functional Groups of Organic Compounds
5. Khan Academy: http://www.khanacademy.org/science/organic-chemistry/organic-structures/functional-groups/v/functional-groups-i

Homework Assignment

Do this assignment about 2 weeks before school starts. Do both worksheets found at the end of the packet and these are due the first day of school. We will have an organic quiz on the third day back.

Have a great summer!

Mrs. Brucker

*Organic pages are from Chapter 24 Brown LeMay 13th edition.

24

The Chemistry of Life: Organic and Biological Chemistry

We are all familiar with how chemical substances can influence our health and behavior. Aspirin, also known as acetylsalicylic acid, relieves aches and pains. Cocaine, whose full chemical name is methyl (1*R*,2*R*,3*S*,5*S*)-3-(benzoyloxy)-8-methyl-8-azabicyclo[3.2.1]octane-2-carboxylate, is a plant-derived substance that is used in clinical situations as an anesthetic, but also is used illegally to experience extreme euphoria (a "high").

Understanding how these molecules exert their effects, and developing new molecules that can target disease and pain, is an enormous part of the modern chemical enterprise. This chapter is about the molecules, composed mainly of carbon, hydrogen, oxygen, and nitrogen, that bridge chemistry and biology.

More than 16 million carbon-containing compounds are known. Chemists make thousands of new compounds every year, about 90% of which contain carbon. The study of compounds whose molecules contain carbon constitutes the branch of chemistry known as **organic chemistry**. This term arose from the eighteenth-century belief that organic compounds could be formed only by living (that is, organic) systems. This idea was disproved in 1828 by the German chemist Friedrich Wöhler when he synthesized urea (H_2NCONH_2), an organic substance found in the urine of mammals, by heating ammonium cyanate (NH_4OCN), an inorganic (nonliving) substance.

▶ **BRAIN ON COCAINE.** These positron-emitting tomography (PET) scans of the human brain show how rapidly glucose is metabolized in different parts of the brain. The top row of images show the brain of a normal person; the bottom two rows of images show the brain of a person who has taken cocaine, after 10 days and after 100 days (red = high glucose metabolism, yellow = medium, blue = low). Notice that glucose metabolism is suppressed in the brain of the person who has taken cocaine.

WHAT'S AHEAD

24.1 GENERAL CHARACTERISTICS OF ORGANIC MOLECULES We begin with a review of the structures and properties of organic compounds.

24.2 INTRODUCTION TO HYDROCARBONS We consider *hydrocarbons*, compounds containing only C and H, including the hydrocarbons called *alkanes*, which contain only single C—C bonds. We also look at *isomers*, compounds with identical compositions but different molecular structures.

24.3 ALKENES, ALKYNES, AND AROMATIC HYDROCARBONS We next explore hydrocarbons with one or more C=C bonds, called *alkenes*, and those with one or more C≡C bonds, called *alkynes*. *Aromatic* hydrocarbons have at least one planar ring with delocalized π electrons.

24.4 ORGANIC FUNCTIONAL GROUPS We recognize that a central organizing principle of organic chemistry is the *functional group*, a group of atoms at which most of the compound's chemical reactions occur.

The study of the chemistry of living species is called *biological chemistry*, *chemical biology*, or **biochemistry**. In this chapter, we present some of the elementary aspects of both organic chemistry and biochemistry.

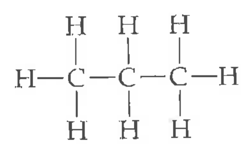
24.1 | General Characteristics of Organic Molecules

What is it about carbon that leads to the tremendous diversity in its compounds and allows it to play such crucial roles in biology and society? Let's consider some general features of organic molecules and, as we do, review principles we learned in earlier chapters.

The Structures of Organic Molecules

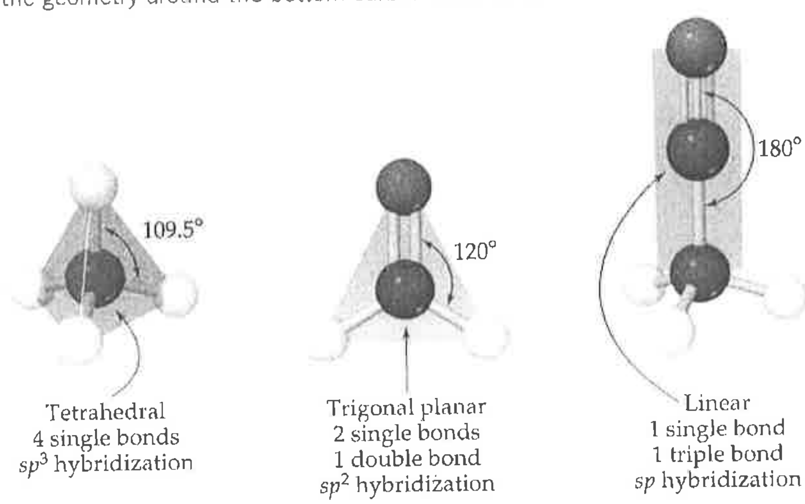
Because carbon has four valence electrons ([He]$2s^2 2p^2$), it forms four bonds in virtually all its compounds. When all four bonds are single bonds, the electron pairs are disposed in a tetrahedral arrangement. (Section 9.2) In the hybridization model, the carbon 2*s* and 2*p* orbitals are then sp^3 hybridized. (Section 9.5) When there is one double bond, the arrangement is trigonal planar (sp^2 hybridization). With a triple bond, it is linear (*sp* hybridization). Examples are shown in ▼ Figure 24.1.

Almost every organic molecule contains C—H bonds. Because the valence shell of H can hold only two electrons, hydrogen forms only one covalent bond. As a result, hydrogen atoms are always located on the *surface* of organic molecules whereas the C—C bonds form the *backbone*, or *skeleton*, of the molecule, as in the propane molecule:



GO FIGURE

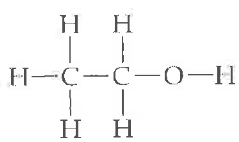
What is the geometry around the bottom carbon atom in acetonitrile?



▲ **Figure 24.1 Carbon geometries.** The three common geometries around carbon are tetrahedral as in methane (CH_4), trigonal planar as in formaldehyde (CH_2O), and linear as in acetonitrile (CH_3CN). Notice that in all cases each carbon atom forms four bonds.

The Stabilities of Organic Substances

Carbon forms strong bonds with a variety of elements, especially H, O, N, and the halogens. (Section 8.8) Carbon also has an exceptional ability to bond to itself, forming a variety of molecules made up of chains or rings of carbon atoms. Most reactions with low or moderate activation energy (Section 14.5) begin when a region of high electron density on one molecule encounters a region of low electron density on another molecule. The regions of high electron density may be due to the presence of a multiple bond or to the more electronegative atom in a polar bond. Because of their strength (the C—C single bond enthalpy is 348 kJ/mol, the C—H bond enthalpy is 413 kJ/mol Table 8.4) and lack of polarity, both C—C single bonds and C—H bonds are relatively unreactive. To better understand the implications of these facts, consider ethanol:



The differences in the electronegativity values of C (2.5) and O (3.5) and of O and H (2.1) indicate that the C—O and O—H bonds are quite polar. Thus, many reactions of ethanol involve these bonds while the hydrocarbon portion of the molecule remains intact. A group of atoms such as the C—O—H group, which determines how an organic molecule reacts (in other words, how the molecule *functions*), is called a **functional group**. The functional group is the center of reactivity in an organic molecule.

Give It Some Thought

Which bond is most likely to be the location of a chemical reaction: C═N, C—C, or C—H?

Solubility and Acid–Base Properties of Organic Substances

In most organic substances, the most prevalent bonds are carbon–carbon and carbon–hydrogen, which are not polar. For this reason, the overall polarity of organic molecules is often low, which makes them generally soluble in nonpolar solvents and not very soluble in water. (Section 13.3) Organic molecules that are soluble in polar solvents are those that have polar groups on the molecule surface, such as glucose and ascorbic acid (► Figure 24.2). Organic molecules that have a long, nonpolar part bonded to a polar, ionic part, such as the stearate ion shown in Figure 24.2, function as *surfactants* and are used in soaps and detergents. (Section 13.6) The nonpolar part of the molecule extends into a nonpolar medium such as grease or oil, and the polar part extends into a polar medium such as water.

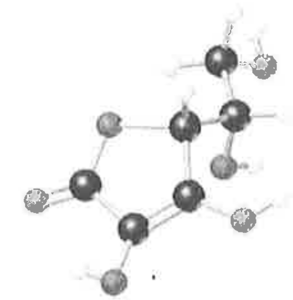
Many organic substances contain acidic or basic groups. The most important acidic organic substances are the carboxylic acids, which bear the functional group —COOH. (Sections 4.3 and 16.10) The most important basic organic substances are amines, which bear the $-NH_2$, —NHR, or $-NR_2$ groups, where R is an organic group made up of carbon and hydrogen atoms. (Section 16.7)

As you read this chapter, you will find many concept links ( ) to related materials in earlier chapters. *We strongly encourage you to follow these links and review the earlier material.* Doing so will enhance your understanding and appreciation of organic chemistry and biochemistry.

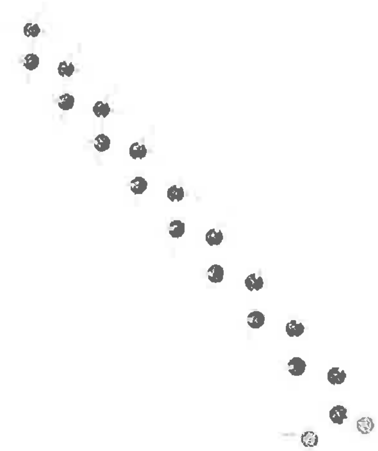
GO FIGURE

How would replacing OH groups on ascorbic acid with CH_3 groups affect the substance's solubility in (**a**) polar solvents and (**b**) nonpolar solvents?

Glucose ($C_6H_{12}O_6$)



Ascorbic acid ($HC_6H_7O_6$)



Stearate ($C_{17}H_{35}COO^-$)

▲ **Figure 24.2 Organic molecules that are soluble in polar solvents.**

24.2 | Introduction to Hydrocarbons

Because carbon compounds are so numerous, it is convenient to organize them into families that have structural similarities. The simplest class of organic compounds is the *hydrocarbons*, compounds composed of only carbon and hydrogen. The key structural feature of hydrocarbons (and of most other organic substances) is the presence of stable carbon–carbon bonds. Carbon is the only element capable of forming stable, extended chains of atoms bonded through single, double, or triple bonds.

Hydrocarbons can be divided into four types, depending on the kinds of carbon–carbon bonds in their molecules. ▼ Table 24.1 shows an example of each type.

Alkanes contain only single C—C bonds. **Alkenes**, also known as *olefins*, contain at least one C═C double bond, and **alkynes** contain at least one C≡C triple bond. In **aromatic hydrocarbons** the carbon atoms are connected in a planar ring structure, joined by both σ and delocalized π bonds between carbon atoms. (Section 8.6) Benzene (C_6H_6) is the best-known example of an aromatic hydrocarbon.

Each type of hydrocarbon exhibits different chemical behaviors, as we will see shortly. The physical properties of all four types, however, are similar in many ways. Because hydrocarbon molecules are relatively nonpolar, they are almost completely insoluble in water but dissolve readily in nonpolar solvents. Their melting points and boiling points are determined by dispersion forces. (Section 11.2) As a result, hydrocarbons of very low molecular weight, such as C_2H_6(bp = −89 °C), are gases at room temperature; those of moderate molecular weight, such as C_6H_{14}(bp = 69 °C), are liquids; and those of high molecular weight, such as $C_{22}H_{46}$(mp = 44 °C), are solids.

▶ Table 24.2 lists the ten simplest alkanes. Many of these substances are familiar because they are used so widely. Methane is a major component of natural gas. Propane is the major component of bottled gas used for home heating and cooking in areas where natural gas is not available. Butane is used in disposable lighters and in fuel canisters for gas camping stoves and lanterns. Alkanes with 5 to 12 carbon atoms per molecule are used to make gasoline. Notice that each succeeding compound in Table 24.2 has an additional CH_2 unit.

Table 24.1 The Four Hydrocarbon Types with Molecular Examples

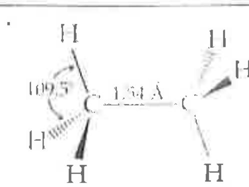
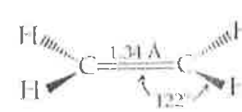
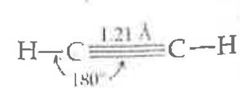
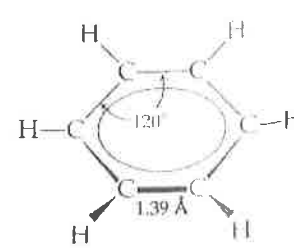
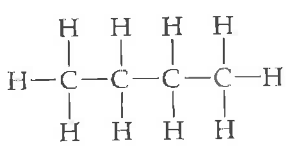
Type	Example			
Alkane	Ethane	CH_3CH_3		
Alkene	Ethylene	$CH_2{=}CH_2$		
Alkyne	Acetylene	$CH{\equiv}CH$		
Aromatic	Benzene	C_6H_6		

Table 24.2 First Ten Members of the Straight-Chain Alkane Series

Molecular Formula	Condensed Structural Formula	Name	Boiling Point (°C)
CH_4	CH_4	Methane	−161
C_2H_6	CH_3CH_3	Ethane	−89
C_3H_8	$CH_3CH_2CH_3$	Propane	−44
C_4H_{10}	$CH_3CH_2CH_2CH_3$	Butane	−0.5
C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	Pentane	36
C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	Hexane	68
C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	Heptane	98
C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Octane	125
C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Nonane	151
$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Decane	174

The formulas for the alkanes given in Table 24.2 are written in a notation called *condensed structural formulas*. This notation reveals the way in which atoms are bonded to one another but does not require drawing in all the bonds. For example, the structural formula and the condensed structural formulas for butane (C_4H_{10}) are



$$H_3C—CH_2—CH_2—CH_3$$

or

$$CH_3CH_2CH_2CH_3$$

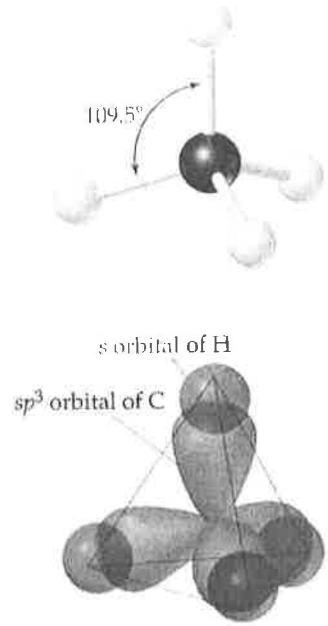
Give It Some Thought

How many C—H and C—C bonds are formed by the middle carbon atom of propane?

Structures of Alkanes

According to the VSEPR model, the molecular geometry about each carbon atom in an alkane is tetrahedral. ∞ (Section 9.2) The bonding may be described as involving sp^3-hybridized orbitals on the carbon, as pictured in ▶ Figure 24.3 for methane. ∞ (Section 9.5)

Rotation about a carbon–carbon single bond is relatively easy and occurs rapidly at room temperature. To visualize such rotation, imagine grasping either methyl group of the propane molecule in ▶ Figure 24.4 and rotating the group relative to the rest of the molecule. Because motion of this sort occurs rapidly in alkanes, a long-chain alkane molecule is constantly undergoing motions that cause it to change its shape, something like a length of chain that is being shaken.

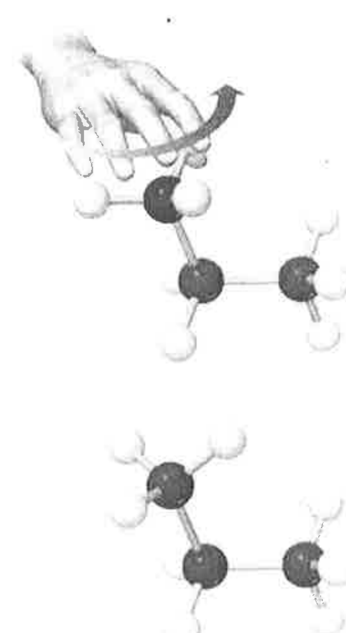


▲ **Figure 24.3 Bonds about carbon in methane.** This tetrahedral molecular geometry is found around all carbons in alkanes.

Structural Isomers

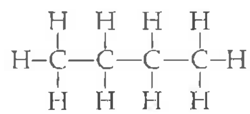
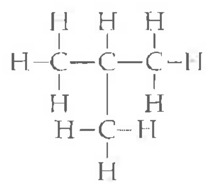
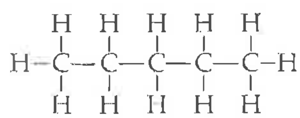
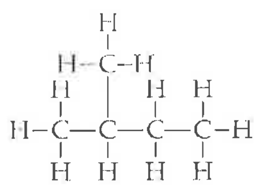
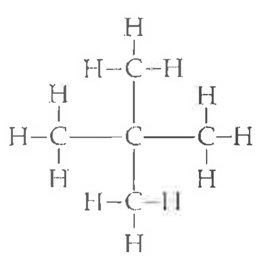
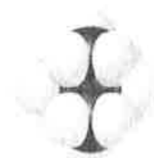
The alkanes in Table 24.2 are called ***straight-chain*** or ***linear hydrocarbons*** because all the carbon atoms are joined in a continuous chain. Alkanes consisting of four or more carbon atoms can also form ***branched chains***, and when they do, they are called ***branched-chain hydrocarbons***. (The branches in organic molecules are often called *side chains*.) Table 24.3, for example, shows all the straight-chain and branched-chain alkanes containing four and five carbon atoms.

Compounds that have the same molecular formula but different bonding arrangements (and hence different structures) are called **structural isomers**. Thus, C_4H_{10} has two structural isomers and C_5H_{12} has three. The structural isomers of a given alkane differ slightly from one another in physical properties, as the melting and boiling points in Table 24.3 indicate.



▲ **Figure 24.4 Rotation about a C—C bond occurs easily and rapidly in all alkanes.**

Table 24.3 Isomers of C_4H_{10} and C_5H_{12}

Systematic Name (Common Name)	Structural Formula	Condensed Structural Formula	Space-filling Model	Melting Point (°C)	Boiling Point (°C)
Butane (*n*-butane)		$CH_3CH_2CH_2CH_3$		−138	−0.5
2-Methylpropane (isobutane)		$CH_3-CH-CH_3$ | CH_3		−159	−12
Pentane (*n*-pentane)		$CH_3CH_2CH_2CH_2CH_3$		−130	+36
2-Methylbutane (isopentane)		CH_3 | $CH_3-CH-CH_2-CH_3$		−160	+28
2,2-Dimethylpropane (neopentane)		CH_3 | CH_3-C-CH_3 | CH_3		−16	+9

The number of possible structural isomers increases rapidly with the number of carbon atoms in the alkane. There are 18 isomers with the molecular formula C_8H_{18}, for example, and 75 with the molecular formula $C_{10}H_{22}$.

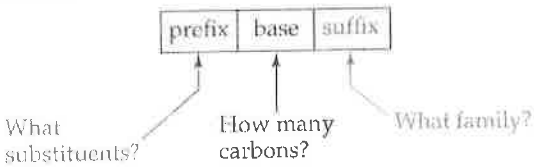
Give It Some Thought

What evidence can you cite to support the fact that although isomers have the same molecular formula they are in fact different compounds?

Nomenclature of Alkanes

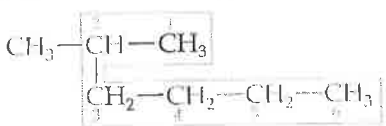
In the first column of Table 24.3, the names in parentheses are called the *common names*. The common name of the isomer with no branches begins with the letter *n* (indicating the "normal" structure). When one CH_3 group branches off the major chain, the common name of the isomer begins with *iso*-, and when two CH_3 groups branch off, the common name begins with *neo*-. As the number of isomers grows, however, it becomes impossible to find a suitable prefix to denote each isomer by a common name. The need for a systematic means of naming organic compounds was recognized as early as 1892, when an organization called the International Union of Chemistry met in Geneva to formulate rules for naming organic substances. Since that time the task of updating the rules for naming compounds has fallen to the International Union of Pure and Applied Chemistry (IUPAC). Chemists everywhere, regardless of their nationality, subscribe to a common system for naming compounds.

The IUPAC names for the isomers of butane and pentane are the ones given first in Table 24.3. These systematic names, as well as those of other organic compounds, have three parts to them:



The following steps summarize the procedures used to name alkanes, which all have names ending with *-ane*. We use a similar approach to write the names of other organic compounds.

1. **Find the longest continuous chain of carbon atoms, and use the name of this chain (given in Table 24.2) as the base name.** Be careful in this step because the longest chain may not be written in a straight line, as in the following structure:



2-Methyl*hexane*

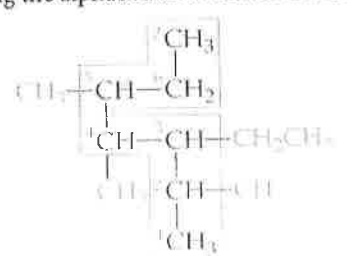
Because the longest continuous chain contains six C atoms, this isomer is named as a substituted hexane. Groups attached to the main chain are called *substituents* because they are substituted in place of an H atom on the main chain. In this molecule, the CH_3 group not enclosed by the blue outline is the only substituent in the molecule.

2. **Number the carbon atoms in the longest chain, beginning with the end nearest a substituent.** In our example, we number the C atoms beginning at the upper right because that places the CH_3 substituent on C2 of the chain. (If we had numbered from the lower right, the CH_3 would be on C5.) The chain is numbered from the end that gives the lower number to the substituent position.

3. **Name each substituent.** A substituent formed by removing an H atom from an alkane is called an **alkyl group**. Alkyl groups are named by replacing the *-ane* ending of the alkane name with *-yl*. The methyl group (CH_3), for example, is derived from methane (CH_4) and the ethyl group (C_2H_5) is derived from ethane (C_2H_6). ▶ Table 24.4 lists six common alkyl groups.

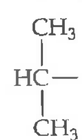
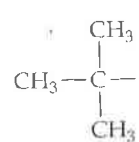
4. **Begin the name with the number or numbers of the carbon or carbons to which each substituent is bonded.** For our compound, the name 2-methylhexane indicates the presence of a methyl group on C2 of a hexane (six-carbon) chain.

5. **When two or more substituents are present, list them in alphabetical order.** The presence of two or more of the same substituent is indicated by the prefixes *di-* (two), *tri-* (three), *tetra-* (four), *penta-* (five), and so forth. The prefixes are ignored in determining the alphabetical order of the substituents:



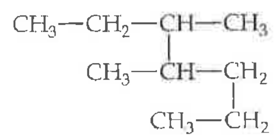
3-Ethyl-2,4,5-trimethylheptane

Table 24.4 Condensed Structural Formulas and Common Names for Several Alkyl Groups

Group	Name
CH_3—	Methyl
CH_3CH_2—	Ethyl
$CH_3CH_2CH_2$—	Propyl
$CH_3CH_2CH_2CH_2$—	Butyl
	Isopropyl
	*tert*-Butyl

SAMPLE EXERCISE 24.1 Naming Alkanes

Give the systematic name for the following alkane:

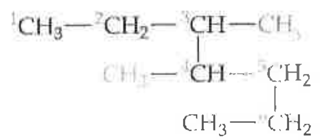


SOLUTION

Analyze We are given the condensed structural formula of an alkane and asked to give its name.

Plan Because the hydrocarbon is an alkane, its name ends in *-ane*. The name of the parent hydrocarbon is based on the longest continuous chain of carbon atoms. Branches are alkyl groups, named after the number of C atoms in the branch and located by counting C atoms along the longest continuous chain.

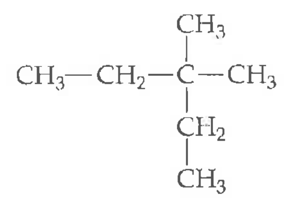
Solve The longest continuous chain of C atoms extends from the upper left CH_3 group to the lower left CH_3 group and is seven C atoms long:



The parent compound is thus heptane. There are two methyl groups branching off the main chain. Hence, this compound is a dimethylheptane. To specify the location of the two methyl groups, we must number the C atoms from the end that gives the lower two numbers to the carbons bearing side chains. This means that we should start numbering at the upper left carbon. There is a methyl group on C3 and one on C4. The compound is thus 3,4-dimethylheptane.

Practice Exercise 1

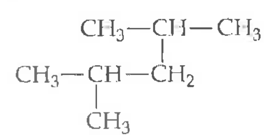
What is the proper name of this compound?



(a) 3-ethyl-3-methylbutane, **(b)** 2-ethyl-2-methylbutane, **(c)** 3,3-dimethylpentane, **(d)** isoheptane, **(e)** 1,2-dimethyl-neopentane.

Practice Exercise 2

Name the following alkane:



SAMPLE EXERCISE 24.2 Writing Condensed Structural Formulas

Write the condensed structural formula for 3-ethyl-2-methylpentane.

SOLUTION

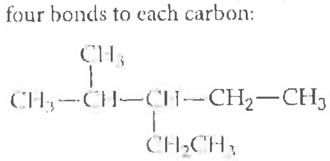
Analyze We are given the systematic name for a hydrocarbon and asked to write its condensed structural formula.

Plan Because the name ends in *-ane*, the compound is an alkane, meaning that all the carbon–carbon bonds are single bonds. The parent hydrocarbon is pentane, indicating five C atoms (Table 24.2). There are two alkyl groups specified, an ethyl group (two carbon atoms, C_2H_5) and a methyl group (one carbon atom, CH_3). Counting from left to right along the five-carbon chain, the name tells us that the ethyl group is attached to C3 and the methyl group is attached to C2.

Solve We begin by writing five C atoms attached by single bonds. These represent the backbone of the parent pentane chain:

C—C—C—C—C

We next place a methyl group on the second C and an ethyl group on the third C of the chain. We then add hydrogens to all the other C atoms to make four bonds to each carbon:



The formula can be written more concisely as

$$CH_3CH(CH_3)CH(C_2H_5)CH_2CH_3$$

where the branching alkyl groups are indicated in parentheses.

Practice Exercise 1

How many hydrogen atoms are in 2,2-dimethylhexane?
(a) 6, **(b)** 8, **(c)** 16, **(d)** 18, **(e)** 20.

Practice Exercise 2

Write the condensed structural formula for 2,3-dimethylhexane.

Cycloalkanes

Alkanes that form rings, or cycles, are called **cycloalkanes**. As ▼ Figure 24.5 illustrates, cycloalkane structures are sometimes drawn as *line structures*, which are polygons in which each corner represents a CH_2 group. This method of representation is similar to that used for benzene rings. (Section 8.6) (Remember from our benzene discussion that in aromatic structures each vertex represents a CH group, not a CH_2 group.)

Carbon rings containing fewer than five carbon atoms are strained because the C—C—C bond angles must be less than the 109.5° tetrahedral angle. The amount of strain increases as the rings get smaller. In cyclopropane, which has the shape of an equilateral triangle, the angle is only 60°; this molecule is therefore much more reactive than propane, its straight-chain analog.

Give It Some Thought

Are the C—C bonds cyclopropane weaker than those in cyclohexane?

Reactions of Alkanes

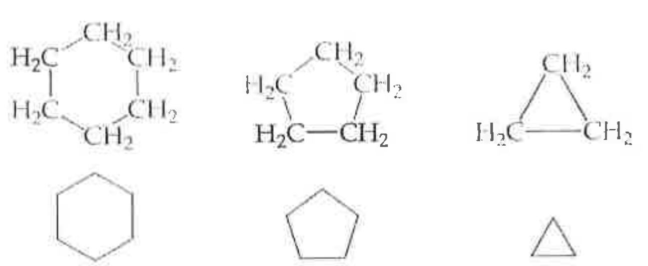
Because they contain only C—C and C—H bonds, most alkanes are relatively unreactive. At room temperature, for example, they do not react with acids, bases, or strong oxidizing agents. Their low chemical reactivity, as noted in Section 24.1, is due primarily to the strength and lack of polarity of C—C and C—H bonds.

Alkanes are not completely inert, however. One of their most commercially important reactions is *combustion* in air, which is the basis of their use as fuels. (Section 3.2) For example, the complete combustion of ethane proceeds according to this highly exothermic reaction:

$$2\,C_2H_6(g) + 7\,O_2(g) \longrightarrow 4\,CO_2(g) + 6\,H_2O(l) \qquad \Delta H^\circ = -2855\ \text{kJ}$$

GO FIGURE

The general formula for straight-chain alkanes is C_nH_{2n+2}. What is the general formula for cycloalkanes?



Cyclohexane — Each vertex represents one CH_2 group

Cyclopentane — Five vertices = five CH_2 groups

Cyclopropane — Three vertices = three CH_2 groups

▲ **Figure 24.5 Condensed structural formulas and line structures for three cycloalkanes.**

Chemistry Put to Work

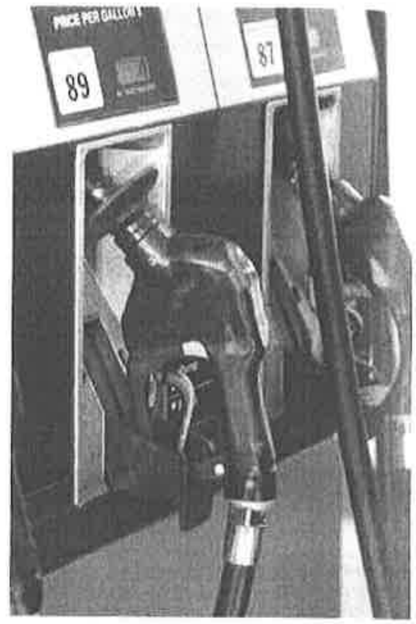
Gasoline

Petroleum, or crude oil, is a mixture of hydrocarbons plus smaller quantities of other organic compounds containing nitrogen, oxygen, or sulfur. The tremendous demand for petroleum to meet the world's energy needs has led to the tapping of oil wells in such forbidding places as the North Sea and northern Alaska.

The usual first step in the *refining*, or processing, of petroleum is to separate it into fractions on the basis of boiling point (▼ **Table 24.5**). Because gasoline is the most commercially important of these fractions, various processes are used to maximize its yield.

Gasoline is a mixture of volatile alkanes and aromatic hydrocarbons. In a traditional automobile engine, a mixture of air and gasoline vapor is compressed by a piston and then ignited by a spark plug. The burning of the gasoline should create a strong, smooth expansion of gas, forcing the piston outward and imparting force along the driveshaft of the engine. If the gas burns too rapidly, the piston receives a single hard slam rather than a strong, smooth push. The result is a "knocking" or "pinging" sound and a reduction in the efficiency with which energy produced by the combustion is converted to work.

The *octane number* of a gasoline is a measure of its resistance to knocking. Gasolines with high octane numbers burn more smoothly and are thus more effective fuels (▶ **Figure 24.6**). Branched alkanes and aromatic hydrocarbons have higher octane numbers than straight-chain alkanes. The octane number of gasoline is obtained by comparing its knocking characteristics with those of isooctane (2,2,4-trimethylpentane) and heptane. Isooctane is assigned an octane number of 100, and heptane is assigned 0. Gasoline with the same knocking characteristics as a mixture of 91% isooctane and 9% heptane, for instance, is rated as 91 octane.



▲ Figure 24.6 **Octane rating.** The octane rating of gasoline measures its resistance to knocking when burned in an engine. The octane rating of the gasoline in the foreground is 89.

Table 24.5 Hydrocarbon Fractions from Petroleum

Fraction	Size Range of Molecules	Boiling-Point Range (°C)	Uses
Gas	C_1 to C_5	−160 to 30	Gaseous fuel, production of H_2
Straight-run gasoline	C_5 to C_{12}	30 to 200	Motor fuel
Kerosene, fuel oil	C_{12} to C_{18}	180 to 400	Diesel fuel, furnace fuel, cracking
Lubricants	C_{16} and up	350 and up	Lubricants
Paraffins	C_{20} and up	Low-melting solids	Candles, matches
Asphalt	C_{36} and up	Gummy residues	Surfacing roads

The gasoline obtained by fractionating petroleum (called *straight-run* gasoline) contains mainly straight-chain hydrocarbons and has an octane number around 50. To increase its octane rating, it is subjected to a process called *reforming*, which converts the straight-chain alkanes into branched-chain ones.

Cracking is used to produce aromatic hydrocarbons and to convert some of the less-volatile fractions of petroleum into compounds suitable for use as automobile fuel. In cracking, the hydrocarbons are mixed with a catalyst and heated to 400–500 °C. The catalysts used are either clay minerals or synthetic Al_2O_3–SiO_2 mixtures. In addition to forming molecules more suitable for gasoline, cracking results in the formation of such low-molecular-weight hydrocarbons as ethylene and propene. These substances are used in a variety of reactions to form plastics and other chemicals.

Adding compounds called either *antiknock agents* or octane enhancers increases the octane rating of gasoline. Until the mid-1970s the principal antiknock agent was tetraethyl lead, $(C_2H_5)_4Pb$. It is no longer used, however, because of the environmental hazards of lead and because it poisons catalytic converters. ([illegible] "Catalytic Converters") Aromatic compounds such as toluene ($C_6H_5CH_3$) and oxygenated hydrocarbons such as ethanol (CH_3CH_2OH) are now generally used as antiknock agents.

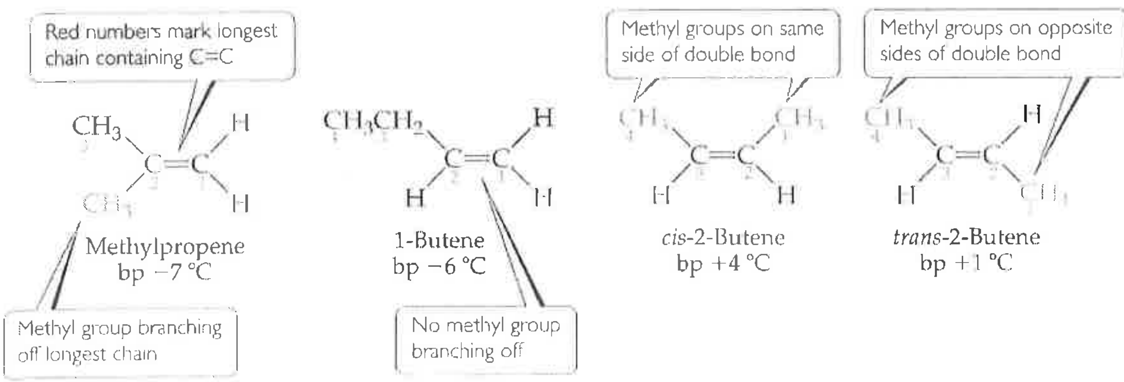
Related Exercises: 24.19 and 24.20

24.3 | Alkenes, Alkynes, and Aromatic Hydrocarbons

Because alkanes have only single bonds, they contain the largest possible number of hydrogen atoms per carbon atom. As a result, they are called *saturated hydrocarbons*. Alkenes, alkynes, and aromatic hydrocarbons contain carbon–carbon multiple bonds (double,

GO FIGURE

How many isomers are there for propene, C_3H_6?



▲ **Figure 24.7 The alkene C_4H_8 has four structural isomers.**

triple, or delocalized π bonds). As a result, they contain less hydrogen than an alkane with the same number of carbon atoms. Collectively, they are called *unsaturated hydrocarbons*. On the whole, unsaturated molecules are more reactive than saturated ones.

Alkenes

Alkenes are unsaturated hydrocarbons that contain at least one C═C bond. The simplest alkene is $CH_2{=}CH_2$, called ethene (IUPAC) or ethylene (common name), which plays important roles as a plant hormone in seed germination and fruit ripening. The next member of the series is $CH_3{-}CH{=}CH_2$, called propene or propylene. Alkenes with four or more carbon atoms have several isomers. For example, the alkene C_4H_8 has the four structural isomers shown in ▲ **Figure 24.7**. Notice both their structures and their names.

The names of alkenes are based on the longest continuous chain of carbon atoms that contains the double bond. The chain is named by changing the ending of the name of the corresponding alkane from *-ane* to *-ene*. The compound on the left in Figure 24.7, for example, has a double bond as part of a three-carbon chain; thus, the parent alkene is propene.

The location of the double bond along an alkene chain is indicated by a prefix number that designates the double-bond carbon atom that is nearest an end of the chain. The chain is always numbered from the end that brings us to the double bond sooner and hence gives the smallest-numbered prefix. In propene, the only possible location for the double bond is between the first and second carbons; thus, a prefix indicating its location is unnecessary. For butene (Figure 24.7), there are two possible positions for the double bond, either after the first carbon (1-butene) or after the second carbon (2-butene).

Give It Some Thought

How many distinct locations are there for a double bond in a five-carbon linear chain?

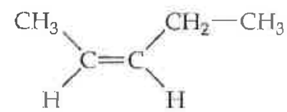
If a substance contains two or more double bonds, the location of each is indicated by a numerical prefix, and the ending of the name is altered to identify the number of double bonds: diene (two), triene (three), and so forth. For example, $CH_2{=}CH{-}CH_2{-}CH{=}CH_2$ is 1,4-pentadiene.

The two isomers on the right in Figure 24.7 differ in the relative locations of their methyl groups. These two compounds are **geometric isomers**, compounds that have the same molecular formula and the same groups bonded to one another

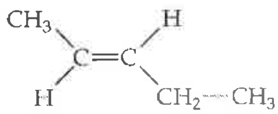
Because the first C atom in 1-pentene is bonded to two H atoms, there are no cis–trans isomers. There are cis and trans isomers for 2-pentene, however. Thus, the three isomers for pentene are

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

1-Pentene



cis-2-Pentene



trans-2-Pentene

(You should convince yourself that *cis*-3-pentene is identical to *cis*-2-pentene and *trans*-3-pentene is identical to *trans*-2-pentene. However, *cis*-2-pentene and *trans*-2-pentene are the correct names because they have smaller numbered prefixes.)

Practice Exercise 1

Which compound does not exist?
(a) 1,2,3,4,5,6,7-octaheptaene, (b) *cis*-2-butane, (c) *trans*-3-hexene,
(d) 1-propene, (e) *cis*-4-decene.

Practice Exercise 2

How many straight-chain isomers are there of hexene, C_6H_{12}?

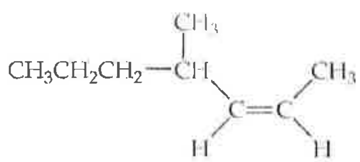
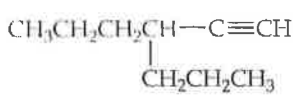
Alkynes

Alkynes are unsaturated hydrocarbons containing one or more $C{\equiv}C$ bonds. The simplest alkyne is acetylene (C_2H_2), a highly reactive molecule. When acetylene is burned in a stream of oxygen in an oxyacetylene torch, the flame reaches about 3200 K. Because alkynes in general are highly reactive, they are not as widely distributed in nature as alkenes; alkynes, however, are important intermediates in many industrial processes.

Alkynes are named by identifying the longest continuous chain containing the triple bond and modifying the ending of the name of the corresponding alkane from *-ane* to *-yne*, as shown in Sample Exercise 24.4.

SAMPLE EXERCISE 24.4 Naming Unsaturated Hydrocarbons

Name the following compounds:

(a)  **(b)** 

SOLUTION

Analyze We are given the condensed structural formulas for an alkene and an alkyne and asked to name the compounds.

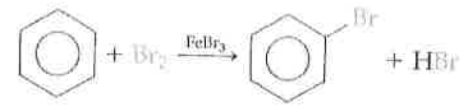
Plan In each case, the name is based on the number of carbon atoms in the longest continuous carbon chain that contains the multiple bond. In the alkene, care must be taken to indicate whether cis–trans isomerism is possible and, if so, which isomer is given.

Solve

(a) The longest continuous chain of carbons that contains the double bond is seven carbons long, so the parent hydrocarbon is heptene. Because the double bond begins at carbon 2 (numbering from the end closer to the double bond), we have 2-heptene. With a methyl group at carbon atom 4, we have 4-methyl-2-heptene. The geometrical configuration at the double bond is cis (that is, the alkyl groups are bonded to the double bond on the same side). Thus, the full name is 4-methyl-*cis*-2-heptene.

In the reaction of Equation 24.11, the principal product is the *meta* isomer.

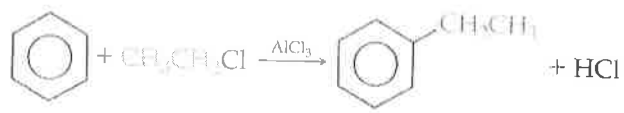
Bromination of benzene, carried out with $FeBr_3$ as a catalyst, is another substitution reaction:



[24.12]

Benzene Bromobenzene

In a similar substitution reaction, called the *Friedel-Crafts reaction*, alkyl groups can be substituted onto an aromatic ring by reacting an alkyl halide with an aromatic compound in the presence of $AlCl_3$ as a catalyst:



[24.13]

Benzene Ethylbenzene

Give It Some Thought

When the aromatic hydrocarbon naphthalene, shown in Figure 24.10, reacts with nitric and sulfuric acids, two compounds containing one nitro group are formed. Draw the structures of these two compounds.

24.4 | Organic Functional Groups

The C═C double bonds of alkenes and C≡C triple bonds of alkynes are just two of many functional groups in organic molecules. As noted earlier, these functional groups each undergo characteristic reactions, and the same is true of all other functional groups. Each kind of functional group often undergoes the same kinds of reactions in every molecule, regardless of the size and complexity of the molecule. Thus, the chemistry of an organic molecule is largely determined by the functional groups it contains.

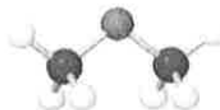
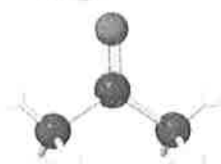
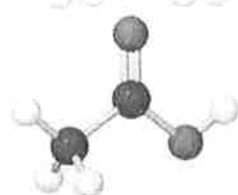
▶ **Table 24.6** lists the most common functional groups. Notice that, except for C═C and C≡C, they all contain either O, N, or a halogen atom, X.

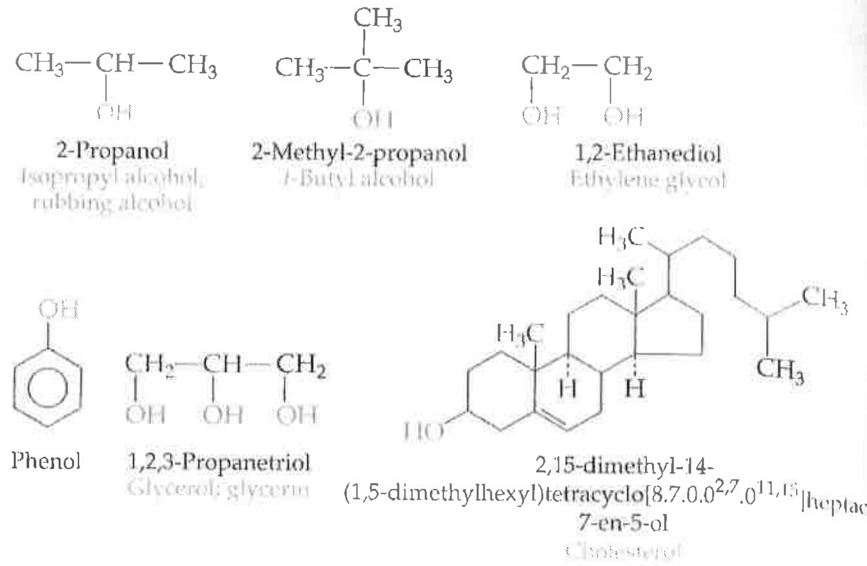
We can think of organic molecules as being composed of functional groups bonded to one or more alkyl groups. The alkyl groups, which are made of C—C and C—H single bonds, are the less reactive portions of the molecules. In describing general features of organic compounds, chemists often use the designation R to represent any alkyl group: methyl, ethyl, propyl, and so on. Alkanes, for example, which contain no functional group, are represented as R—H. Alcohols, which contain the functional group —OH, are represented as R—OH. If two or more different alkyl groups are present in a molecule, we designate them R, R′, R″, and so forth.

Alcohols

Alcohols are compounds in which one or more hydrogens of a parent hydrocarbon have been replaced by the functional group —OH, called either the

Table 24.6 Common Functional Groups

Functional Group	Compound Type	Suffix or Prefix	Example: Structural Formula	Example: Ball-and-stick Model	Example: Systematic Name (common name)
$>C=C<$	Alkene	*-ene*	$H_2C=CH_2$		**Ethene** (Ethylene)
$-C\equiv C-$	Alkyne	*-yne*	$H-C\equiv C-H$		Ethyne (Acetylene)
$-\overset{\vert}{\underset{\vert}{C}}-\ddot{\underset{..}{O}}-H$	Alcohol	*-ol*	$H_3C-\ddot{O}-H$		**Methanol** (Methyl alcohol)
$-\overset{\vert}{\underset{\vert}{C}}-\ddot{\underset{..}{O}}-\overset{\vert}{\underset{\vert}{C}}-$	Ether	*ether*	$H_3C-\ddot{O}-CH_3$		Dimethyl ether
$-\overset{\vert}{\underset{\vert}{C}}-\ddot{\underset{..}{X}}:$ (X = halogen)	Alkyl halide or haloalkane	*-ide*	$H_3C-\ddot{\underset{..}{Cl}}:$		**Chloromethane** (Methyl chloride)
$-\overset{\vert}{\underset{\vert}{C}}-\ddot{\underset{\vert}{N}}-$	Amine	*-amine*	$H_3C-CH_2-\ddot{N}H_2$		Ethylamine
$-\overset{:O:}{\overset{\Vert}{C}}-H$	**Aldehyde**	***-al***	$H_3C-\overset{:O:}{\overset{\Vert}{C}}-H$		**Ethanal** (Acetaldehyde)
$-\overset{\vert}{\underset{\vert}{C}}-\overset{:O:}{\overset{\Vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$	Ketone	*-one*	$H_3C-\overset{:O:}{\overset{\Vert}{C}}-CH_3$		Propanone (Acetone)
$-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-H$	Carboxylic acid	*-oic acid*	$H_3C-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-H$		Ethanoic acid (Acetic acid)
$-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-\overset{\vert}{\underset{\vert}{C}}-$	Ester	*-oate*	$H_3C-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-CH_3$		Methyl ethanoate (Methyl acetate)
$-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{\vert}{N}}-$	Amide	*-amide*	$H_3C-\overset{:O:}{\overset{\Vert}{C}}-\ddot{N}H_2$		Ethanamide (Acetamide)



▲ **Figure 24.11 Condensed structural formulas of six important alcohols.** Common names are given in blue.

hydroxyl group or the *alcohol group*. Note in ▲ Figure 24.11 that the name for an alcohol ends in *-ol*. The simple alcohols are named by changing the last letter in the name of the corresponding alkane to *-ol*—for example, ethan*e* becomes ethan*ol*. Where necessary, the location of the OH group is designated by a numeric prefix that indicates the number of the carbon atom bearing the OH group.

The O—H bond is polar, so alcohols are more soluble in polar solvents than are hydrocarbons. The —OH functional group can also participate in hydrogen bonding. As a result, the boiling points of alcohols are higher than those of their parent alkanes.

◀ Figure 24.12 shows several commercial products that consist entirely or in large part of an alcohol.

▲ **Figure 24.12 Everyday alcohols.** Many of the products we use every day—from rubbing alcohol to hair spray and antifreeze—are composed either entirely or mainly of alcohols.

The simplest alcohol, methanol (methyl alcohol), has many industrial uses and is produced on a large scale by heating carbon monoxide and hydrogen under pressure in the presence of a metal oxide catalyst:

$$CO(g) + 2\,H_2(g) \xrightarrow[400\,^\circ C]{200-300\text{ atm}} CH_3OH(g) \qquad [24.14]$$

Because methanol has a very high octane rating as an automobile fuel, it is used as a gasoline additive and as a fuel in its own right.

Ethanol (ethyl alcohol, C_2H_5OH) is a product of the fermentation of carbohydrates such as sugars and starches. In the absence of air, yeast cells convert these carbohydrates into ethanol and CO_2:

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2\,C_2H_5OH(aq) + 2\,CO_2(g) \qquad [24.15]$$

In the process, the yeast cells derive energy necessary for growth. This reaction is carried out under carefully controlled conditions to produce beer, wine, and other beverages in which ethanol (called just "alcohol" in everyday language) is the active ingredient.

The simplest polyhydroxyl alcohol (an alcohol containing more than one OH group) is 1,2-ethanediol (ethylene glycol, $HOCH_2CH_2OH$), the major ingredient in automobile antifreeze. Another common polyhydroxyl alcohol is 1,2,3-propanetriol (glycerol, $HOCH_2CH(OH)CH_2OH$), a viscous liquid that dissolves readily in water and is used in cosmetics as a skin softener and in foods and candies to keep them moist.

Phenol is the simplest compound with an OH group attached to an aromatic ring. One of the most striking effects of the aromatic group is the greatly increased acidity of the OH group. Phenol is about 1 million times more acidic in water than a nonaromatic alcohol. Even so, it is not a very strong acid ($K_a = 1.3 \times 10^{-10}$). Phenol is used industrially to make plastics and dyes, and as a topical anesthetic in throat sprays.

Cholesterol, shown in Figure 24.11, is a biochemically important alcohol. The OH group forms only a small component of this molecule, so cholesterol is only slightly soluble in water (2.6 g/L of H_2O). Cholesterol is a normal and essential component of our bodies; when present in excessive amounts, however, it may precipitate from solution. It precipitates in the gallbladder to form crystalline lumps called *gallstones*. It may also precipitate against the walls of veins and arteries and thus contribute to high blood pressure and other cardiovascular problems.

Ethers

Compounds in which two hydrocarbon groups are bonded to one oxygen are called **ethers**. Ethers can be formed from two molecules of alcohol by eliminating a molecule of water. The reaction is catalyzed by sulfuric acid, which takes up water to remove it from the system:

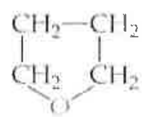
$$CH_3CH_2{-}OH + H{-}OCH_2CH_3 \xrightarrow{H_2SO_4} CH_3CH_2{-}O{-}CH_2CH_3 + H_2O \qquad [24.16]$$

A reaction in which water is eliminated from two substances is called a *condensation reaction*. (Sections 12.8 and 22.8)

Both diethyl ether and the cyclic ether tetrahydrofuran, shown below, are common solvents for organic reactions. Diethyl ether was formerly used as an anesthetic (known simply as "ether" in that context), but it had significant side effects.

$CH_3CH_2{-}O{-}CH_2CH_3$

Diethyl ether



Tetrahydrofuran (THF)

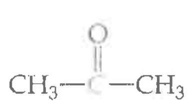
Aldehydes and Ketones

Several of the functional groups listed in Table 24.6 contain the **carbonyl group**, C=O. This group, together with the atoms attached to its carbon, defines several important functional groups that we consider in this section.

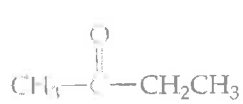
In **aldehydes**, the carbonyl group has at least one hydrogen atom attached:

Methanal (Formaldehyde) Ethanal (Acetaldehyde)

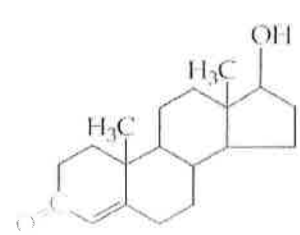
In **ketones**, the carbonyl group occurs at the interior of a carbon chain and is therefore flanked by carbon atoms:



Propanone (Acetone)



2-Butanone (Methyl ethyl ketone)



Testosterone

The systematic names of aldehydes contain *-al* and that ketone names contain *-one*. Notice that testosterone has both alcohol and ketone groups; the ketone functional group dominates the molecular properties. Therefore, testosterone is considered a ketone first and an alcohol second, and its name reflects its ketone properties.

Many compounds found in nature contain an aldehyde or ketone functional group. Vanilla and cinnamon flavorings are naturally occurring aldehydes. Two isomers of the ketone carvone impart the characteristic flavors of spearmint leaves and caraway seeds.

Ketones are less reactive than aldehydes and are used extensively as solvents. Acetone, the most widely used ketone, is completely miscible with water, yet it dissolves a wide range of organic substances.

Carboxylic Acids and Esters

Carboxylic acids contain the *carboxyl* functional group, often written COOH. (Section 16.10) These weak acids are widely distributed in nature and are common in citrus fruits. (Section 4.3) They are also important in the manufacture of polymers used to make fibers, films, and paints. ▼ **Figure 24.13** shows the formulas of several carboxylic acids.

The common names of many carboxylic acids are based on their historical origins. Formic acid, for example, was first prepared by extraction from ants; its name is derived from the Latin word *formica*, "ant."

Carboxylic acids can be produced by oxidation of alcohols. Under appropriate conditions, the aldehyde may be isolated as the first product of oxidation, as in the sequence

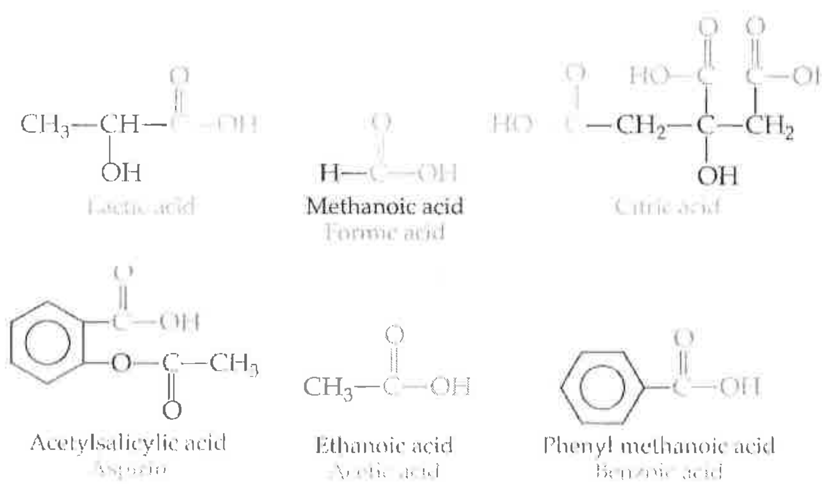
$$\underset{\text{Ethanol}}{CH_3CH_2OH} + (O) \longrightarrow \underset{\text{Acetaldehyde}}{CH_3\overset{\overset{\displaystyle O}{\|}}{C}H} + H_2O \qquad [24.17]$$

$$\underset{\text{Acetaldehyde}}{CH_3\overset{\overset{\displaystyle O}{\|}}{C}H} + (O) \longrightarrow \underset{\text{Acetic acid}}{CH_3\overset{\overset{\displaystyle O}{\|}}{C}OH} \qquad [24.18]$$

where (O) represents any oxidant that can provide oxygen atoms. The air oxidation of ethanol to acetic acid is responsible for causing wines to turn sour, producing vinegar.

GO FIGURE

Which of these substances have both a carboxylic acid functional group and an alcohol functional group?



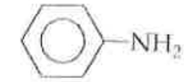
▲ **Figure 24.13 Structural formulas of common carboxylic acids.** The monocarboxylic acids are generally referred to by their common names, given in blue type.

Amines and Amides

Amines are compounds in which one or more of the hydrogens of ammonia (NH_3) are replaced by an **alkyl group**:

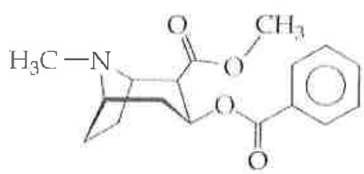
$CH_3CH_2NH_2$ — Ethylamine

$(CH_3)_3N$ — Trimethylamine

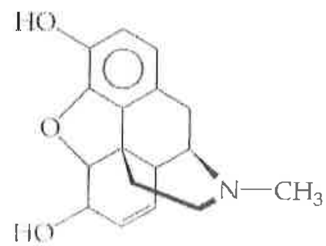


Phenylamine
Aniline

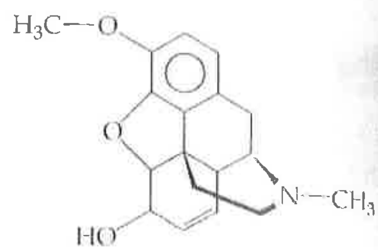
Amines are the most common organic bases. (Section 16.7) As we saw in the Chemistry Put to Work box in Section 16.8, many pharmaceutically active compounds are complex amines:



Cocaine



Morphine

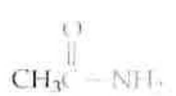


Codeine

An amine with at least one H bonded to N can undergo a condensation reaction with a carboxylic acid to form an **amide**, which contains the carbonyl group (C═O) attached to N (Table 24.6):

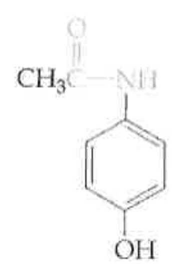
$$CH_3\overset{\overset{\displaystyle O}{\|}}{C}-OH + H-N(CH_3)_2 \longrightarrow CH_3\overset{\overset{\displaystyle O}{\|}}{C}-N(CH_3)_2 + H_2O \qquad [24.22]$$

We may consider the amide functional group to be derived from a carboxylic acid with an NRR′, NH_2 or NHR′ group replacing the OH of the acid, as in these examples:



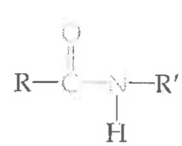
Ethanamide
Acetamide

Phenylmethanamide
Benzamide



N-(4-hydroxyphenyl)ethanamide
Acetaminophen

The amide linkage

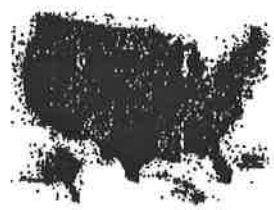


where R and R′ are organic groups, is the key functional group in proteins, as we will see in Section 24.7.

How to recognize how many **SIG FIGS** are in a number and how to use SIG FIGS in your calculations:

SIG FIGS:

1. Where do sig figs come from and why are they important?
    a. SIG FIGS actually come from measurements with an instrument. In a written problem, you take the numbers that refer to measurement at face value for sig figs because they came from measurements—e.g., length, mass, temperature, volume, even moles and molarity, etc. These all quantify something via one or more instruments. They reflect the precision of the measuring device and not the calculator's ability to print out (too) many decimal places in the case of irrational numbers.
    b. DO NOT USE conversion factors or constants for sig figs.
    c. DO NOT USE counting numbers (discrete numbers) for sig figs, e.g., 2.54 cm = 1 inch or 100 cm = 1 m or 25 students per 1 class section. Use neither the 2.54, the100, the 25 nor the 1's for sig figs.
2. *How many sig figs are in a given number?* Students often get confused about numbers like 0.00040. Use the Atlantic-Pacific rule to distinguish between digits that are place holders and digits that are significant.

<u>P</u>acific side  <u>A</u>tlantic side

If a decimal point is <u>A</u>bsent from the number, start counting from the <u>A</u>tlantic side of the number; begin counting with the first non-zero digit and every digit thereafter *including* any zeroes.

If a decimal point is <u>P</u>resent in the number, start counting from the <u>P</u>acific side of the number; begin counting with the first non-zero digit and every digit thereafter *including* any zeroes.

A few examples (sig figs are bolded):

2.000 2000 10100 1.0090 19000 0.010

3. How to add and subtract with sig figs: line up the numbers at the decimal point, then add or subtract.
The answer can have the same number of decimal places as the addend with the <u>*least*</u> *number of decimal places.*
Note: there is no mention of the words "sig figs" in that last sentence. It only mentions number of decimal places. But that *is* the sig figs rule for addition/subtraction.

Ex. Add: 21.500 g + 3.45 g + 2.95 g = 8.90 g (3 sig figs in the sum, 2 decimal places)

Subtract: 22.3406 g – 12.24 g = 10.10 g (4 sig figs in the difference, 2 decimal places)

4. Multiplication and division: *The product or quotient can have the same number of sig figs as the factor with the least number of sig figs.*

   a. Ex. (5.20 cm) (2.0001 cm) (1.903 cm) = 19.8 cm^3

Finally, when reading the length of a line or the volume in a cylinder or buret, read the digits as indicated by the marked increments and then estimate one more digit, that is, one *beyond* the marked increment lines.

ION TABLES

Cations

Metals with Multiple Charges

Ion Formula	Systematic Name	Classical Name
Fe^{2+}	Iron (II) ion	Ferrous
Fe^{3+}	Iron (III) ion	Ferric
Cu^{+}	Copper(I) ion	Cuprous
Cu^{2+}	Copper (II) ion	Cupric
Pb^{2+}	Lead (II) ion	Plumbous
Pb^{4+}	Lead (IV) ion	Plumbic
Hg_2^{2+}	Mercury (I) ion	Mercurous
Hg^{2+}	Mercury (II) ion	Mercuric
Cr^{2+}	Chromium (II) ion	Chromous
Cr^{3+}	Chromium (III) ion	Chromic
Co^{2+}	Cobalt (II) ion	Cobaltous
Co^{3+}	Cobalt (III) ion	Cobaltic
Sn^{2+}	Tin (II) ion	Stannous
Sn^{4+}	Tin (IV) ion	Stannic
Mn^{2+}	Manganese (II) ion	Manganous
Mn^{3+}	Manganese (III) ion	Manganic
Ni^{2+}	Nickel (II) ion	Nickelous
Ni^{3+}	Nickel (III) ion	Nickelic

Metals with only one charge

Ion Formula	Systemic Name	Ion Formula	Systemic Name
Al^{3+}	Aluminum ion	Zn^{2+}	Zinc ion
Ag^{+}	Silver ion	Cd^{2+}	Cadmium ion

Polyatomic Ions

Cation NH_4^+ Ammonium

Anions

-1 charge		-2 charge	
Ion Formula	**Name**	**Ion Formula**	**Name**
OH^-	Hydroxide	CO_3^{2-}	Carbonate
CN^-	Cyanide	CrO_4^{2-}	Chromate
MnO_4^-	Permanganate	$Cr_2O_7^{2-}$	Dichromate
HCO_3^-	Hydrogen Carbonate	$C_2O_4^{2-}$	Oxalate
ClO^-	Hypochlorite	O_2^{2-}	Peroxide
ClO_2^-	Chlorite		
ClO_3^-	Chlorate		
ClO_4^-	Perchlorate		
$C_2H_3O_2^-$	Acetate		
H^-	Hydride		

Oxyanion

-1 charge		-2 charge		-3 charge	
Ion Formula	**Name**	**Ion Formula**	**Name**	**Ion Formula**	**Name**
NO_2^-	Nitrite	SO_3^{2-}	Sulfite	PO_3^{3-}	Phosphite
NO_3^-	Nitrate	SO_4^{2-}	Sulfate	PO_4^{3-}	Phosphate
HSO_3^-	Hydrogen sulfite	HPO_4^{2-}	Hydrogen phosphate		
HSO_4^-	Hydrogen sulfate	$C_2O_4^{2-}$	Oxalate		
$H_2PO_4^-$	Dihydrogen phosphate	$S_2O_3^{2-}$	Thiosulfate		

Solubility of (some but not all) Ionic Compounds in Water—<u>MEMORIZE</u> THIS TABLE!

Negative ions (anions) +	Positive ions (cations)	Form compounds which are
1. ALL	Alkali ions (from Group IA: Li^+, Na^+, K^+, Rb^+, Cs^+)	Soluble i.e., > 0.1 mole/L
2. ALL	Ammonium ion, NH_4^+	Soluble
3. Nitrate, NO_3^-	ALL	Soluble
4. Acetate, CH_3COO^-	ALL	Soluble
5. Chloride, Cl^- Bromide, Br^- Iodide, I^-	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+ ALL OTHERS	NOT soluble Soluble
6. Sulfate, SO_4^{2-}	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ag^+, Pb^{2+} ALL OTHERS	NOT soluble Soluble
7. Sulfide, S^{2-}	Alkali ions, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+} ALL OTHERS	Soluble NOT soluble
8. Hydroxide, OH^-	Alkali ions, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+} ALL OTHERS	Soluble NOT soluble
9. Phosphate, PO_4^{3-} Carbonate, CO_3^{2-} Sulfite, SO_3^{2-}	Alkali ions and NH_4^+ ALL OTHERS	Soluble NOT soluble
10. Chromate, CrO_4^{2-}	Alkali ions, NH_4^+, Ca^{2+}, Cu^{2+}, Mg^{2+} ALL OTHERS	Soluble NOT soluble
11. Oxalate, $C_2O_4^{2-}$	Alkali ions (except Li^+), NH_4^+ ALL OTHERS	Soluble NOT soluble

***Common Elements & their symbols**—Learn these <u>by</u> <u>heart!</u>*

Aluminum	Al
Argon	Ar
Barium	Ba
Bromine	Br
Calcium	Ca
Carbon	C
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Fluorine	F
Gold	Au
Helium	He
Hydrogen	H
Iodine	I
Iron	Fe
Lead	Pb
Lithium	Li
Magnesium	Mg
Manganese	Mn
Mercury	Hg
Nickel	Ni
Nitrogen	N
Oxygen	O
Phosphorus	P
Potassium	K
Silver	Ag
Sodium	Na
Strontium	Sr
Sulfur	S
Tin	Sn
Zinc	Zn

Stoichiometry Worksheet Review Name______________________

1. Given the following equation: 2 C_4H_{10} + 13 O_2 ---> 8 CO_2 + 10 H_2O, show what the following molar ratios should be.

a. C_4H_{10} / O_2
b. O_2 / CO_2
c. O_2 / H_2O
d. C_4H_{10} / CO_2

2. Given the following equation: 2 $KClO_3$ ---> 2 KCl + 3 O_2

How many moles of O_2 can be produced by letting 12.00 moles of $KClO_3$ react?

3. Given the following equation: 2 K + Cl_2 ---> 2 KCl

How many grams of KCl is produced from 2.50 g of K and excess Cl_2. From 1.00 g of Cl_2 and excess K?

4. Given the following equation: Na_2O + H_2O ---> 2 NaOH

How many grams of NaOH is produced from 1.20 x 10^2 grams of Na_2O? How many grams of Na_2O are required to produce 1.60 x 10^2 grams of NaOH?

5. Given the following equation: 8 Fe + S_8 ---> 8 FeS

What mass of iron is needed to react with 16.0 grams of sulfur? How many grams of FeS are produced?

6. Given the following equation: 2 $NaClO_3$ ---> 2 NaCl + 3 O_2

12.00 moles of $NaClO_3$ will produce how many grams of O_2? How many grams of NaCl are produced when 80.0 grams of O_2 are produced?

7. The average human requires 120.0 grams of glucose ($C_6H_{12}O_6$) per day. How many grams of CO_2 (in the photosynthesis reaction) are required for this amount of glucose? The photosynthetic reaction is: 6 CO_2 + 6 H_2O → $C_6H_{12}O_6$ + 6 O_2

* For your test you will need to know how to create a balanced equation from the question.

AP Chemistry
Mrs. Brucker

PRACTICE NAMING WORKSHEET

	Ionic or Molecular	Formula or Name
1. K_2SO_4	______	____________________
2. Barium cyanide	______	____________________
3. $NaNO_3$	______	____________________
4. Dichlorine monoxide	______	____________________
5. Lithium oxalate	______	____________________
6. $Mg_3(PO_4)_2$	______	____________________
7. $CsC_2H_3O_2$	______	____________________
8. Chromium (II) fluoride	______	____________________
9. P_4S_{10}	______	____________________
10. Sn_3N_2	______	____________________
11. Calcium hydroxide	______	____________________
12. Stronium chromate	______	____________________
13. PbS	______	____________________
14. Barium hydrogen carbonate	______	____________________
15. N_2O_4	______	____________________
16. Manganese (III) dichromate	______	____________________
17. Tetrasulfur tetranitride	______	____________________
18. $(NH_4)_3PO_4$	______	____________________
19. NBr_3	______	____________________
20. Copper (II) bromide	______	____________________
21. $Fe_2(CO_3)_3$	______	____________________

22. Silver phosphide _______ _______________________________

23. Aluminum nitrite _______ _______________________________

24. $Mn(HSO_4)_2$ _______ _______________________________

25. Iron (III) acetate _______ _______________________________

26. PCl_3 _______ _______________________________

27. Mercury (I) hydrogen phospahte _______ _______________________________

28. Ammonium oxide _______ _______________________________

29. $Ca_3(PO_3)_2$ _______ _______________________________

30. IF_5 _______ _______________________________

31. FeP _______ _______________________________

32. HCl _______ _______________________________

33. Sodium permanganate _______ _______________________________

34. Acetic acid _______ _______________________________

35. $Sr(HSO_3)_2$ _______ _______________________________

36. $NaNO_2$ _______ _______________________________

37. HNO_3 _______ _______________________________

38. Copper (I) phosphite _______ _______________________________

39. KOH _______ _______________________________

40. Nitrogen dioxide _______ _______________________________

41. P_2O_3 _______ _______________________________

42. Magnesium dihydrogen phosphate _______ _______________________________

43. Tin(IV) oxide _______ _______________________________

44. Calcium chromate _______ _______________________________