

**A LECTURE NOTE  
ON  
TH.2B – ENGINEERING  
CHEMISTRY  
SEMESTER -2**



**Prepared by – Sri Bipin Bihari Mohanty, (Chemistry)**

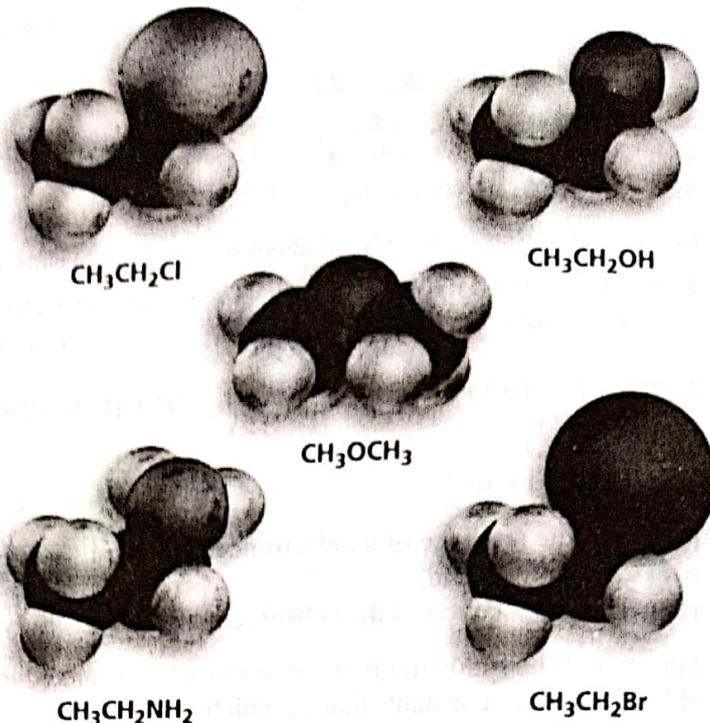
**Lecture STAGE -II**

**Mechanical Engineering**

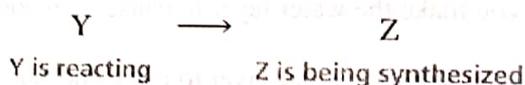
**GOVT. POLYTECHNIC,  
MALKANGIRI**

# An Introduction to Organic Compounds:

Nomenclature, Physical Properties, and Representation of Structure



This book organizes organic chemistry according to how organic compounds react. However, we must not forget that whenever an organic compound undergoes a reaction, a new organic compound is synthesized. In other words, while we are learning how organic compounds react, we will also be learning how to synthesize new compounds.



The main classes of compounds that are synthesized by the reactions we will study in Chapters 3–11 are alkanes, alkyl halides, ethers, alcohols, and amines. As we learn how to synthesize compounds, we will need to be able to refer to them by name. So we will begin our study of organic chemistry by learning how to name these five classes of compounds.

First we will learn how to name alkanes because they form the basis for the names of almost all organic compounds. **Alkanes** are composed of only carbon atoms and hydrogen atoms and contain only single bonds. (A **hydrocarbon** is a compound that is composed of only carbon and hydrogen, so an alkane is a hydrocarbon that has only single bonds.) Alkanes in which the carbons form a continuous chain with no branches are called **straight-chain alkanes**. The names of several straight-chain alkanes are given in Table 2.1. It is important that you learn the names of at least the first 10.

The family of alkanes shown in Table 2.1 is an example of a homologous series. A **homologous series** (*homos* is Greek for “the same as”) is a family of compounds in which each member differs from the next by one **methylene ( $\text{CH}_2$ ) group**. The members of a homologous series are called **homologs**. Propane ( $\text{CH}_3\text{CH}_2\text{CH}_3$ ) and butane ( $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ ) are homologs.

By looking at the relative numbers of carbon and hydrogen atoms in the alkanes listed in Table 2.1, you can conclude that the general molecular formula for an alkane is  $\text{C}_n\text{H}_{2n+2}$ , where  $n$  is any integer. So, if an alkane has one carbon atom, it must

have four hydrogen atoms; if it has two carbon atoms, it must have six hydrogens. We have seen that carbon forms four covalent bonds and hydrogen forms only one covalent bond (Section 1.4). This means that there is only one possible structure for an alkane with molecular formula  $\text{CH}_4$  (methane), and only one structure for an alkane with molecular formula  $\text{C}_2\text{H}_6$  (ethane). We have examined the structures of these compounds in Section 1.7. There is also only one structure for an alkane with molecular formula  $\text{C}_3\text{H}_8$  (propane).

name	Kekulé structure	condensed structure	ball-and-stick model
methane	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$	$\text{CH}_4$	
ethane	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_3$	
propane	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_2\text{CH}_3$	
butane	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	



3-D Molecules:  
Propane;  
Butane

As the number of carbons in the alkane increases, the number of possible structures also increases. There are two possible structures for an alkane with molecular formula  $\text{C}_4\text{H}_{10}$ . In addition to butane—a straight-chain alkane—there is a branched butane called isobutane. Both of these structures fulfill the requirement that each carbon bonds to four atoms and each hydrogen forms only one bond.

Compounds such as butane and isobutane that have the same molecular formula but differ in the order in which the atoms are connected are called **constitutional isomers** (their molecules have different constitutions). In fact, isobutane got its name because it is an “iso”mer of butane. The structural unit with two methyl groups and a hydrogen bonded to a carbon that occurs in isobutane has come to be called “iso.” Thus, the name isobutane tells you that it is a four-carbon alkane with an iso structural unit.

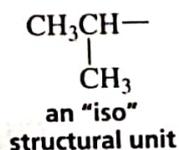
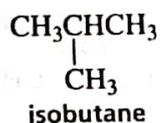
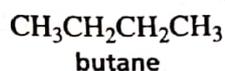
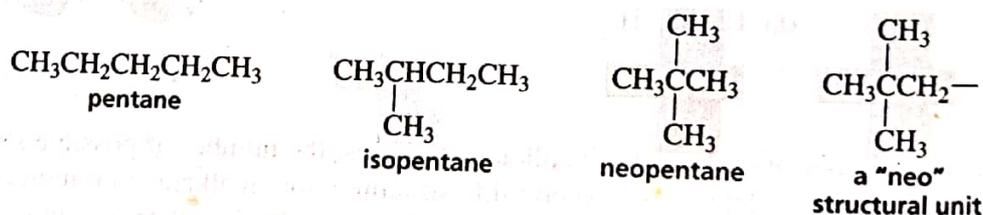


TABLE 2.1 Nomenclature and Physical Properties of Straight-Chain Alkanes

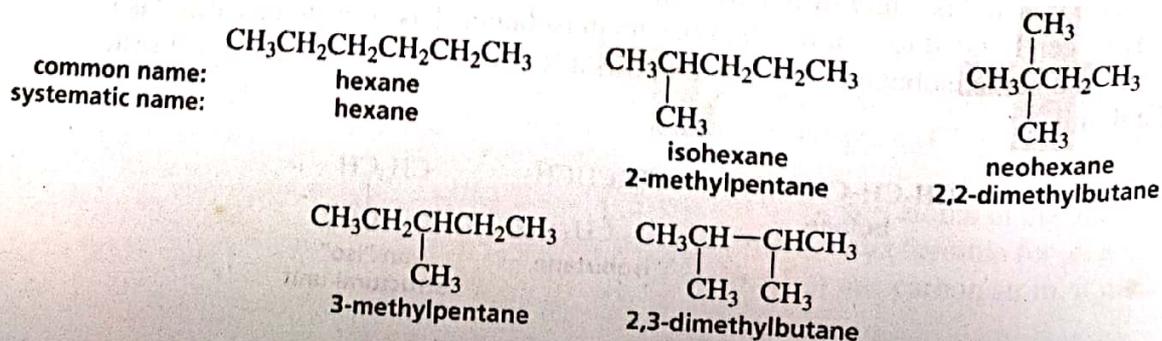
Number of carbons	Molecular formula	Name	Condensed structure	Boiling point (°C)	Melting point (°C)	Density <sup>a</sup> (g/mL)
1	CH <sub>4</sub>	methane	CH <sub>4</sub>	-167.7	-182.5	
2	C <sub>2</sub> H <sub>6</sub>	ethane	CH <sub>3</sub> CH <sub>3</sub>	-88.6	-183.3	
3	C <sub>3</sub> H <sub>8</sub>	propane	CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub>	-42.1	-187.7	
4	C <sub>4</sub> H <sub>10</sub>	butane	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	-0.5	-138.3	
5	C <sub>5</sub> H <sub>12</sub>	pentane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	36.1	-129.8	0.5572
6	C <sub>6</sub> H <sub>14</sub>	hexane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	68.7	-95.3	0.6603
7	C <sub>7</sub> H <sub>16</sub>	heptane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>5</sub> CH <sub>3</sub>	98.4	-90.6	0.6837
8	C <sub>8</sub> H <sub>18</sub>	octane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>6</sub> CH <sub>3</sub>	127.7	-56.8	0.7026
9	C <sub>9</sub> H <sub>20</sub>	nonane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>7</sub> CH <sub>3</sub>	150.8	-53.5	0.7177
10	C <sub>10</sub> H <sub>22</sub>	decane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>8</sub> CH <sub>3</sub>	174.0	-29.7	0.7299
11	C <sub>11</sub> H <sub>24</sub>	undecane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>9</sub> CH <sub>3</sub>	195.8	-25.6	0.7402
12	C <sub>12</sub> H <sub>26</sub>	dodecane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>10</sub> CH <sub>3</sub>	216.3	-9.6	0.7487
13	C <sub>13</sub> H <sub>28</sub>	tridecane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>11</sub> CH <sub>3</sub>	235.4	-5.5	0.7546
20	C <sub>20</sub> H <sub>42</sub>	eicosane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>18</sub> CH <sub>3</sub>	343.0	36.8	0.7886
21	C <sub>21</sub> H <sub>44</sub>	heneicosane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>19</sub> CH <sub>3</sub>	356.5	40.5	0.7917
30	C <sub>30</sub> H <sub>62</sub>	triacontane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>28</sub> CH <sub>3</sub>	449.7	65.8	0.8097

<sup>a</sup>Density is temperature-dependent. The densities given are those determined at 20 °C (*d*<sup>20°</sup>).

There are three alkanes with molecular formula C<sub>5</sub>H<sub>12</sub>. Pentane is the straight-chain alkane. Isopentane, as its name indicates, has an iso structural unit and five carbon atoms. The third isomer is called neopentane. The structural unit with a carbon surrounded by four other carbons is called "neo."

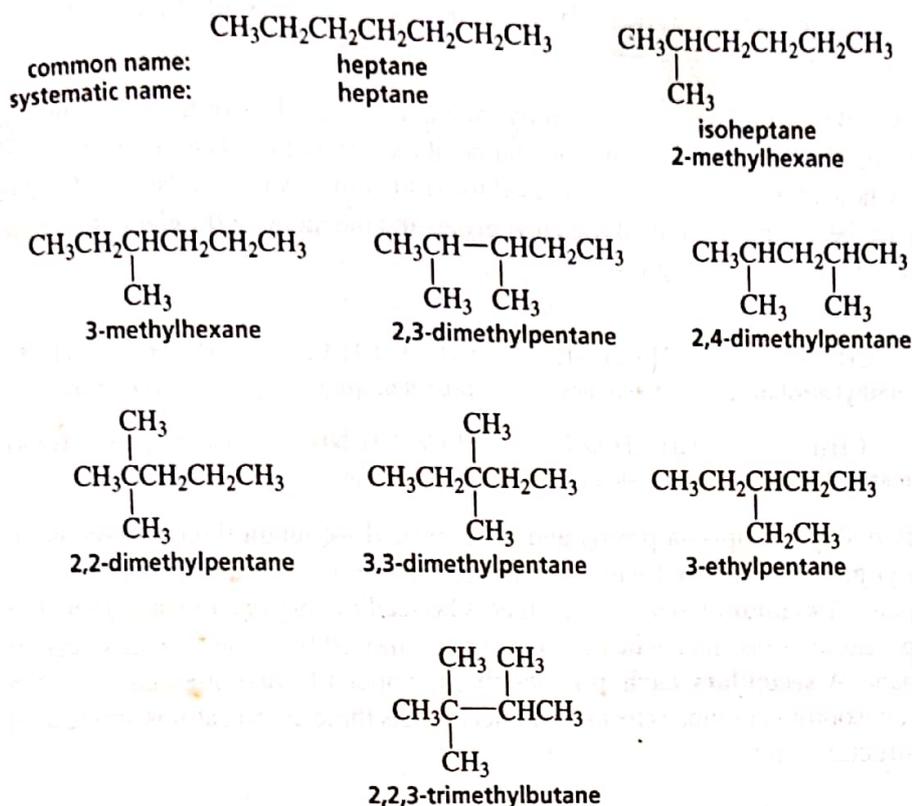


There are five isomers with molecular formula C<sub>6</sub>H<sub>14</sub>. We are now able to name three of them (hexane, isohexane, and neohexane), but we cannot name the other two without defining names for new structural units. (At this point, ignore the names written in blue.)



There are nine isomers with molecular formula  $C_7H_{16}$ . We can name only two of them (heptane and isoheptane) without defining new structural units. Notice that neoheptane cannot be used as a name because three different heptanes have a carbon that is bonded to four other carbons and a name must be specific to only one compound.

A compound can have more than one name, but a name must specify only one compound.



The number of different structural units increases rapidly as the number of carbons in an alkane increases. For example, there are 75 alkanes with molecular formula  $C_{10}H_{22}$  and 4347 alkanes with molecular formula  $C_{15}H_{32}$ . To avoid having to memorize the names of many different structural units, chemists have devised rules that name compounds on the basis of their structures. This way, only the rules have to be learned. Because the name is based on the structure, these rules make it possible to deduce the structure of a compound from its name.

This method of nomenclature is called **systematic nomenclature**. It is also called **IUPAC nomenclature** because it was designed by a commission of the International Union of Pure and Applied Chemistry (abbreviated IUPAC and pronounced "Eye-You-Pack") at a meeting in Geneva, Switzerland, in 1892. The IUPAC rules have been continually revised by the commission since then. Names such as isobutane and neopentane—nonsystematic names—are called **common names** and are shown in red in this text. The systematic or IUPAC names are shown in blue for all of the alkanes with six and seven carbon atoms. Before we can understand how an IUPAC name for an alkane is constructed, we must learn how to name alkyl substituents.

Removal of a hydrogen from an alkane results in an **alkyl substituent** (or an alkyl group). Alkyl substituents are named by replacing the "ane" ending of the alkane with "yl." The letter "R" is used to indicate any alkyl group.

## 2.1 NOMENCLATURE OF ALKYL SUBSTITUENTS

$CH_3-$   
a methyl group

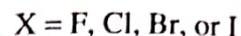
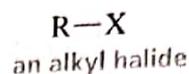
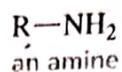
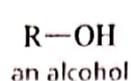
$CH_3CH_2-$   
an ethyl group

$CH_3CH_2CH_2-$   
a propyl group

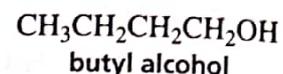
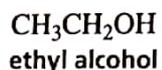
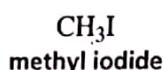
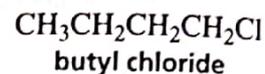
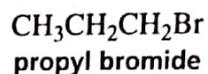
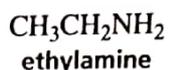
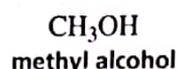
$CH_3CH_2CH_2CH_2-$   
a butyl group

R—  
any alkyl group

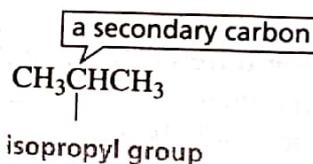
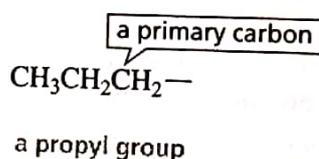
If a hydrogen of an alkane is replaced by an OH, the compound becomes an **alcohol**; if it is replaced by an NH<sub>2</sub>, the compound becomes an **amine**; and if it is replaced by a halogen, the compound becomes an **alkyl halide**.



An alkyl group name followed by the name of the class of the compound (alcohol, amine, etc.) yields the common name of the compound. The following examples show how alkyl group names are used to build common names. Notice that there is a space between the name of the alkyl group and the name of the class of compound, except in the case of amines.

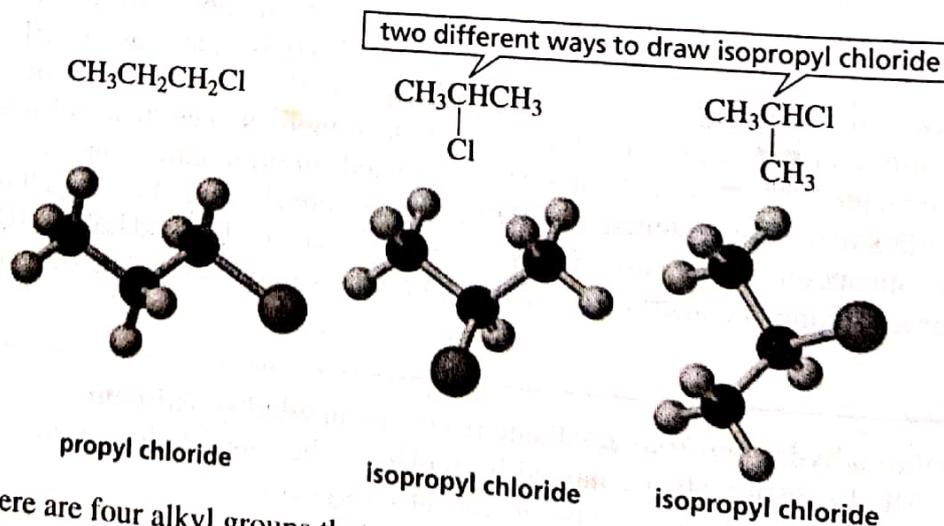


Two alkyl groups—a propyl and an isopropyl—contain three carbon atoms. A propyl group is obtained when a hydrogen is removed from a primary carbon of propane. A **primary carbon** is one that is bonded to only one other carbon. An isopropyl group is obtained when a hydrogen is removed from the secondary carbon of propane. A **secondary carbon** is one that is bonded to two other carbons. Notice that an isopropyl group, as its name indicates, has three carbon atoms arranged as an iso structural unit.



Build models of the two representations of isopropyl chloride and convince yourself that they represent the same compound.

Molecular structures can be drawn in different ways. Isopropyl chloride, for example, is drawn here in two ways. Both represent the same compound because the central carbon in each is bonded to a hydrogen, a chlorine, and two methyl groups.

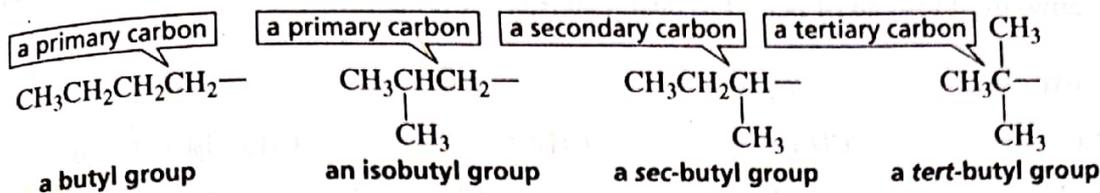


There are four alkyl groups that contain four carbons. Butyl and isobutyl groups have both had a hydrogen removed from a primary (1°) carbon. A *sec*-butyl group has had a hydrogen removed from a secondary (2°) carbon (*sec*-, often abbreviated *s*-, stands for secondary); and a *tert*-butyl group has had a hydrogen removed from

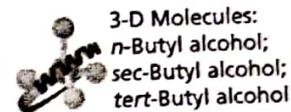
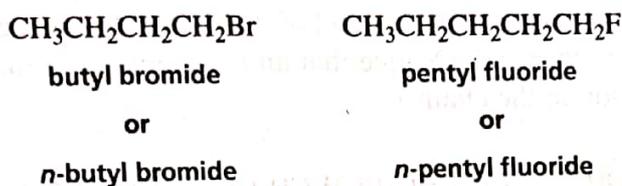
3-D Molecules:  
Propyl chloride;  
Isopropyl chloride

a tertiary ( $3^\circ$ ) carbon (*tert-*, sometimes abbreviated *t-*, stands for tertiary). A **tertiary carbon** is one that is bonded to three other carbons.

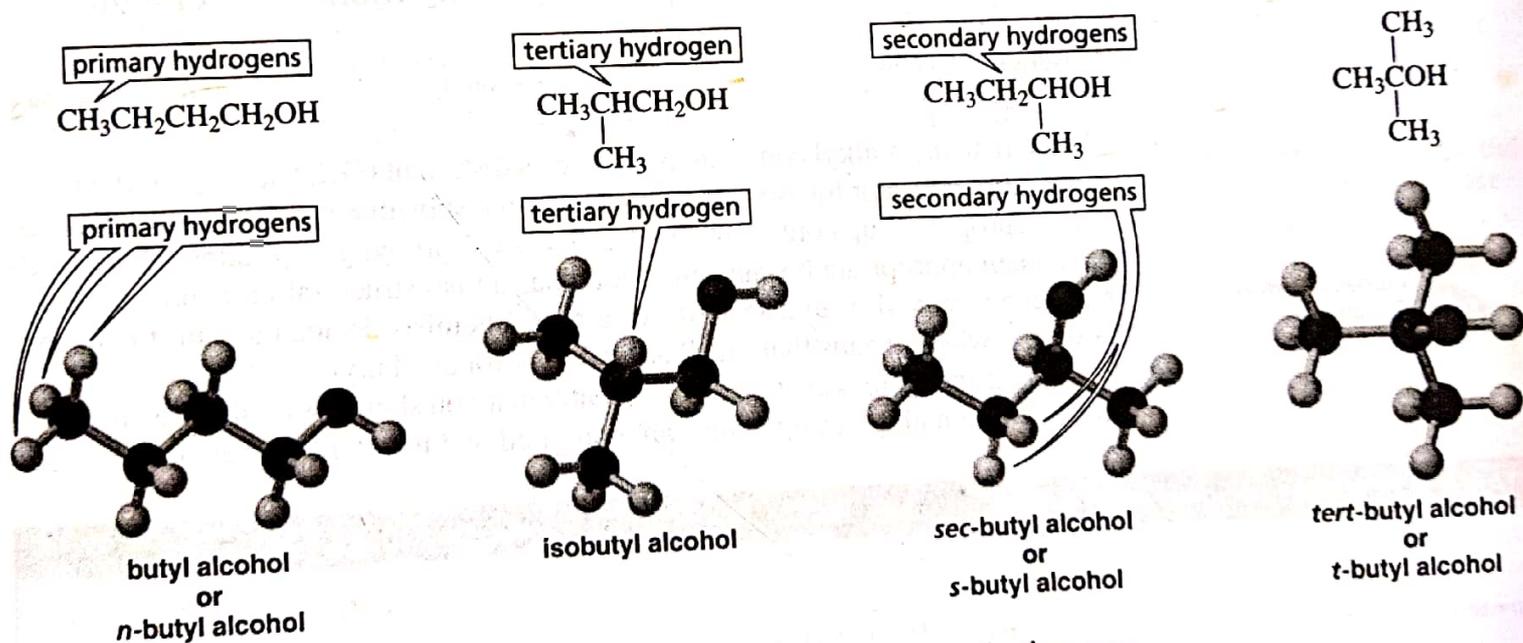
A **primary carbon** is bonded to one carbon, a **secondary carbon** is bonded to two carbons, and a **tertiary carbon** is bonded to three carbons.



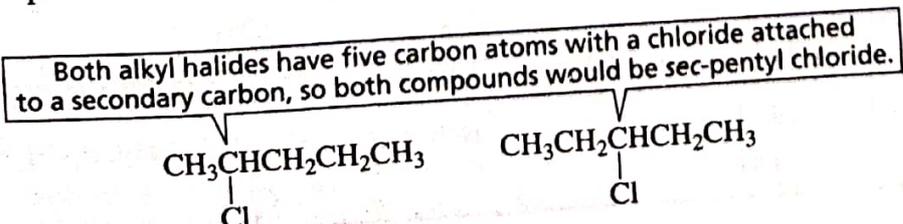
A straight-chain alkyl group is sometimes called *n*-butyl (*n* for normal) to emphasize that its four carbon atoms are in an unbranched chain. However, if the name does not have a prefix such as "*n*" or "*iso*," it is assumed that the carbons are in an unbranched chain.



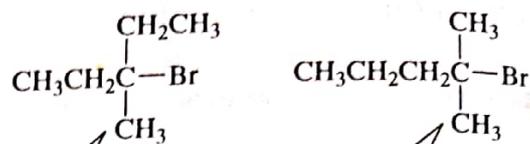
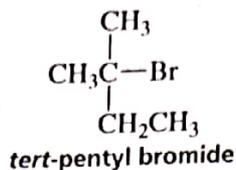
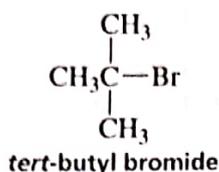
The hydrogens in a molecule are also referred to as primary, secondary, and tertiary. **Primary hydrogens** are attached to primary carbons, **secondary hydrogens** are attached to secondary carbons, and **tertiary hydrogens** are attached to tertiary carbons.



Because a chemical name must apply to only one compound, the only time you will see the prefix "*sec*" is in *sec*-butyl. The name "*sec*-pentyl" cannot be used because pentane has two different secondary carbon atoms. Therefore, there are two different alkyl groups that result from the removal of a hydrogen from a secondary carbon of pentane.

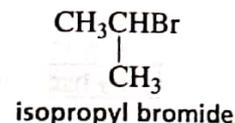
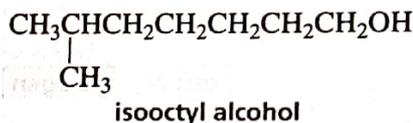
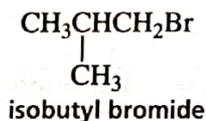
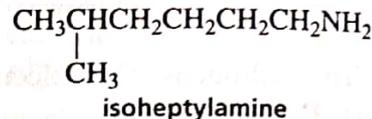
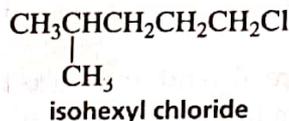
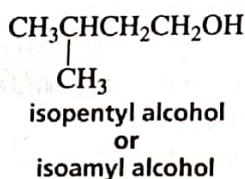


The prefix "tert" is found in *tert*-butyl and *tert*-pentyl because each of these substituent names describes only one alkyl group. The name "*tert*-hexyl" cannot be used because it describes two different alkyl groups. (In older literature, you might find amyl used instead of pentyl to designate five carbons.)



Both alkyl bromides have six carbon atoms with a bromine attached to a tertiary carbon, so both compounds would be *tert*-hexyl bromide.

The prefix "iso" can be used regardless of the number of carbons in the alkyl group. This prefix means that there is an iso structural unit (a carbon bonded to two methyl groups and a hydrogen) at one end of the molecule, and any group replacing a hydrogen is at the other end. (Notice that an iso group has a methyl group on the next to the last carbon in the chain.)



Notice that *all* isoalkyl compounds have the substituent (OH, Cl, NH<sub>2</sub>, etc.) on a primary carbon except for isopropyl, which has the substituent on a secondary carbon. The isopropyl group could have been called a *sec*-propyl group. Either name would have been appropriate because the group has an iso structural unit and a hydrogen has been removed from a secondary carbon. Chemists decided to call it isopropyl, however, which means that "*sec*" is used only for *sec*-butyl.

Alkyl group names are used so frequently that you should learn them. Some of the most common alkyl group names are compiled in Table 2.2 for your convenience.

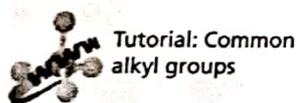


TABLE 2.2 Names of Some Alkyl Groups

methyl	CH <sub>3</sub> —	<i>sec</i> -butyl	$\begin{array}{c} \text{CH}_3\text{CH}_2\text{CH}- \\   \\ \text{CH}_3 \end{array}$	neopentyl	$\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3\text{CCH}_2- \\   \\ \text{CH}_3 \end{array}$
ethyl	CH <sub>3</sub> CH <sub>2</sub> —			hexyl	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> —
propyl	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> —			isohexyl	$\begin{array}{c} \text{CH}_3\text{CHCH}_2\text{CH}_2\text{CH}_2- \\   \\ \text{CH}_3 \end{array}$
isopropyl	$\begin{array}{c} \text{CH}_3\text{CH}- \\   \\ \text{CH}_3 \end{array}$	<i>tert</i> -butyl	$\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3\text{C}- \\   \\ \text{CH}_3 \end{array}$	heptyl	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> —
butyl	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> —	pentyl	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> —	isoheptyl	$\begin{array}{c} \text{CH}_3\text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2- \\   \\ \text{CH}_3 \end{array}$
isobutyl	$\begin{array}{c} \text{CH}_3\text{CHCH}_2- \\   \\ \text{CH}_3 \end{array}$	isopentyl	$\begin{array}{c} \text{CH}_3\text{CHCH}_2\text{CH}_2- \\   \\ \text{CH}_3 \end{array}$		

**PROBLEM 1**

Write a structure for each of the following compounds:

a. isopropyl alcohol

c. *sec*-butyl iodide

e. *tert*-butylamine

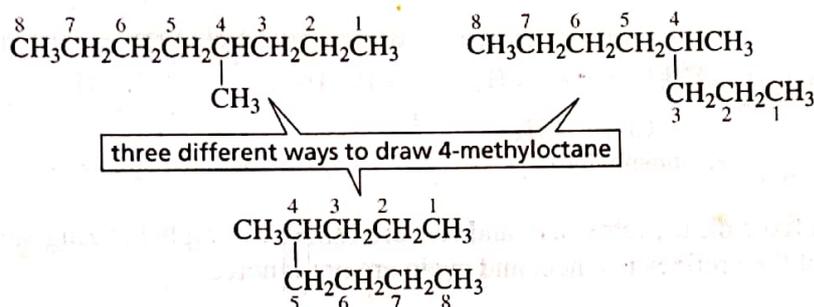
b. isopentyl fluoride

d. neopentyl chloride

f. isooctyl bromide

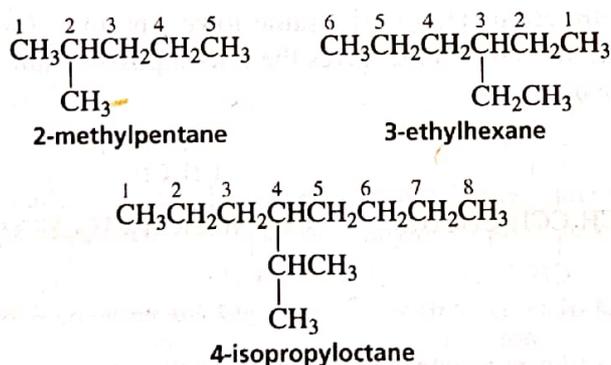
The systematic name of an alkane is obtained using the following rules:

1. Determine the number of carbons in the longest continuous carbon chain. This chain is called the **parent hydrocarbon**. The alkane name indicating the number of carbons in the parent hydrocarbon becomes the alkane's "last name." Notice that the longest continuous chain is chosen regardless of how the molecule is written. Sometimes you have to "turn a corner" to obtain the longest continuous chain.



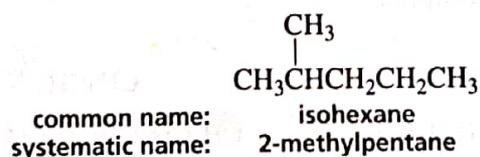
2. The name of the alkyl substituent that hangs off the parent hydrocarbon is cited before the name of the parent hydrocarbon with a number to designate the carbon to which it is attached. The chain is numbered in the direction that gives the substituent as low a number as possible. The substituent name and the name of the parent hydrocarbon are joined in one word, and there is a hyphen between the number and the substituent name.

Number the chain so that the substituent gets the lowest possible number.



Notice that only systematic names have numbers; common names never contain numbers.

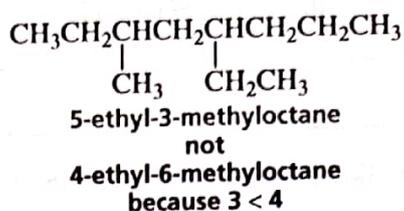
Numbers are used only for systematic names and never for common names.



3. If more than one substituent is attached to the parent hydrocarbon, the chain is numbered in the direction that will result in the lowest possible number in the name

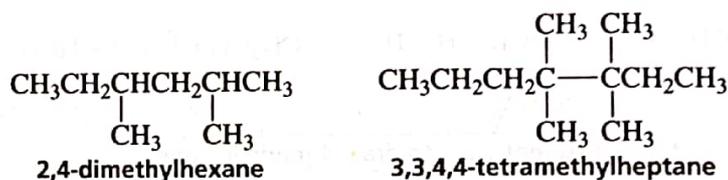
List substituents in alphabetical order.

of the compound. The substituents are listed in alphabetical order (not numerical order), with each substituent getting the appropriate number. In the following example, the correct name (5-ethyl-3-methyloctane) contains a 3 as its lowest number, while the incorrect name (4-ethyl-6-methyloctane) contains a 4 as its lowest number.



A number and a word are separated by a hyphen; numbers are separated by a comma.

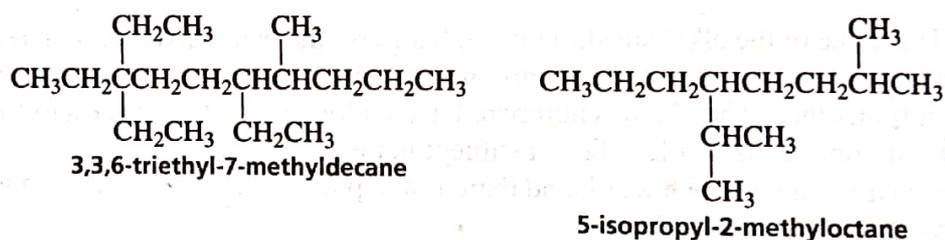
If two or more substituents are the same, the prefixes di, tri, and tetra are used with the substituent names. The numbers indicating the locations of the identical substituents are cited together, separated by commas. Notice that there must be as many numbers in a name as there are substituents.



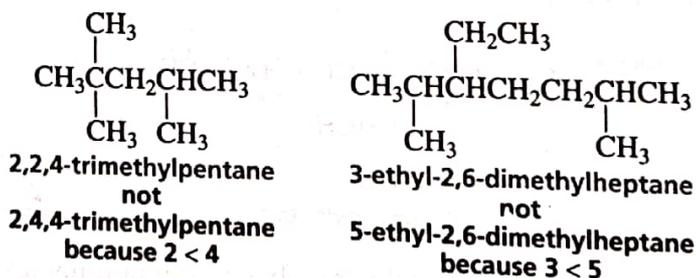
di, tri, tetra, sec, and tert are ignored in alphabetizing.

The prefixes di, tri, tetra, *sec*, and *tert* are ignored in alphabetizing substituent groups, but the prefixes iso, neo, and cyclo are not ignored.

iso, neo, and cyclo are not ignored in alphabetizing.

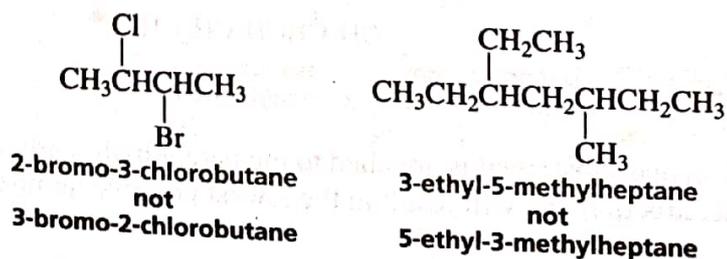


4. When both directions lead to the same lowest number for one of the substituents, the direction is chosen that gives the lowest possible number to one of the remaining substituents.

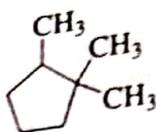


Only if the same set of numbers is obtained in both directions does the first cited group get the lower number.

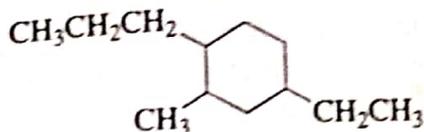
5. If the same substituent numbers are obtained in both directions, the first cited group receives the lower number.







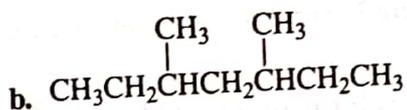
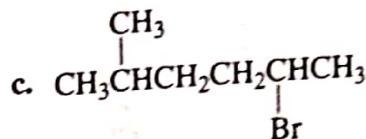
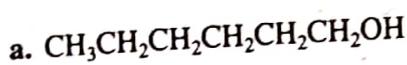
1,1,2-trimethylcyclopentane  
not  
1,2,2-trimethylcyclopentane  
because 1 < 2  
not  
1,1,5-trimethylcyclopentane  
because 2 < 5



4-ethyl-2-methyl-1-propylcyclohexane  
not  
1-ethyl-3-methyl-4-propylcyclohexane  
because 2 < 3  
not  
5-ethyl-1-methyl-2-propylcyclohexane  
because 4 < 5

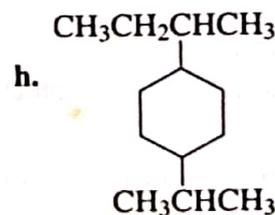
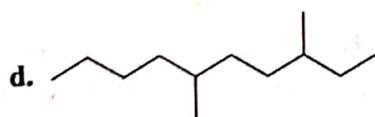
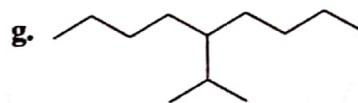
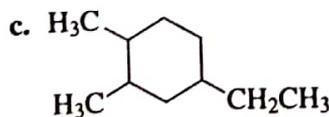
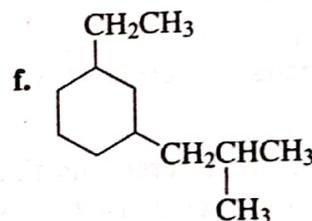
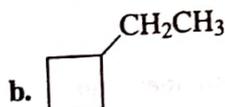
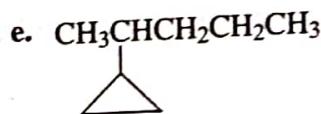
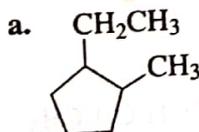
### PROBLEM 5

Convert the following condensed structures into skeletal structures. (Remember that condensed structures show atoms but few, if any, bonds; skeletal structures show bonds but few, if any, atoms.)



### PROBLEM 6

Give the systematic name for each of the following compounds:



## 2.4 NOMENCLATURE OF ALKYL HALIDES

Alkyl halides are compounds in which a hydrogen of an alkane has been replaced by a halogen. Alkyl halides are classified as primary, secondary, or tertiary depending on the carbon to which the halogen is attached. The halogen is bonded to a primary carbon (a carbon bonded to one other carbon) in a **primary alkyl halide**, to a secondary carbon (a carbon bonded to two other carbons) in a **secondary alkyl**

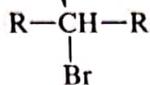
**halide**, and to a tertiary carbon (a carbon bonded to three other carbons) in a **tertiary alkyl halide**. The nonbonding electrons on the halogens are generally not shown unless they are needed to draw your attention to some chemical property of the atom.

a primary carbon



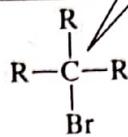
a primary alkyl halide

a secondary carbon



a secondary alkyl halide

a tertiary carbon



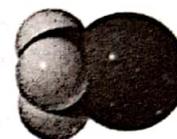
a tertiary alkyl halide



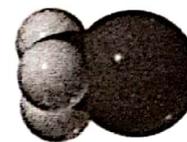
$\text{CH}_3\text{F}$   
methyl fluoride



$\text{CH}_3\text{Cl}$   
methyl chloride

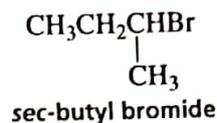
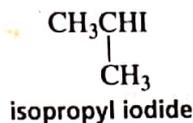
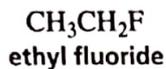
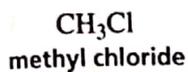


$\text{CH}_3\text{Br}$   
methyl bromide

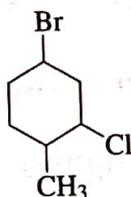
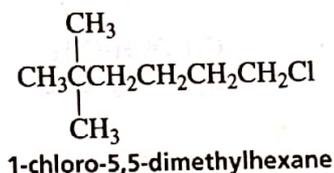
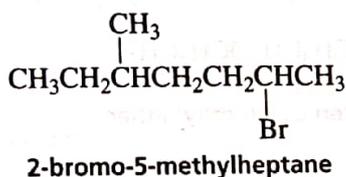


$\text{CH}_3\text{I}$   
methyl iodide

The common names of alkyl halides are obtained by citing the name of the alkyl group followed by the name of the halogen.



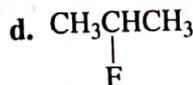
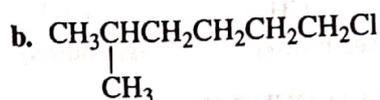
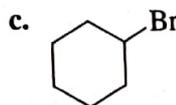
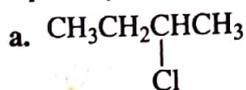
In the IUPAC system, alkyl halides are named as substituted alkanes. The substituent prefix names for the halogens replace the "ine" ending in the name of the element with "o" (i.e., fluoro, chloro, bromo, iodo). Therefore, alkyl halides are often called haloalkanes.



4-bromo-2-chloro-1-methylcyclohexane

**PROBLEM 7**

Give two names for each of the following compounds and tell whether each alkyl halide is primary, secondary, or tertiary.

**PROBLEM 8**

Draw a–c by substituting a chlorine for a hydrogen of methylcyclohexane. Name each of the alkyl halides.

a. primary alkyl halide

b. three different secondary alkyl halides

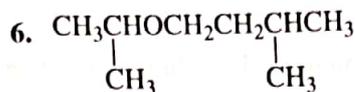
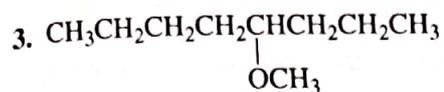
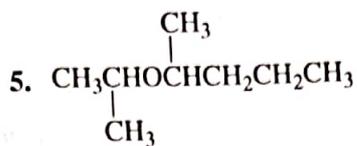
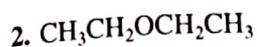
c. a tertiary alkyl halide



3-D Molecules:  
Methyl fluoride;  
Methyl chloride;  
Methyl bromide;  
Methyl iodide

**PROBLEM 10**

a. What is the systematic (IUPAC) name for each of the following ethers?



b. Do all of these ethers have common names?

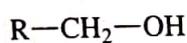
c. What are their common names?



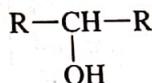
Tutorial: Nomenclature of ethers

Alcohols are compounds in which a hydrogen of an alkane has been replaced by an OH group. Alcohols are classified as **primary alcohols**, **secondary alcohols**, or **tertiary alcohols** depending on whether the OH group is bonded to a primary, secondary, or tertiary carbon. This is similar to the way alkyl halides are classified.

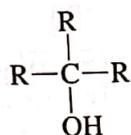
## 2.6 NOMENCLATURE OF ALCOHOLS



a primary alcohol

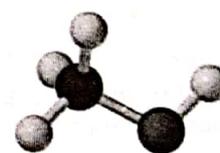
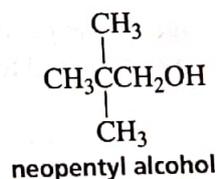
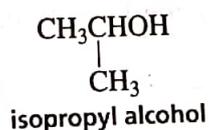
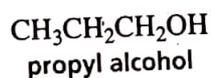
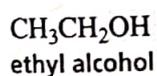


a secondary alcohol

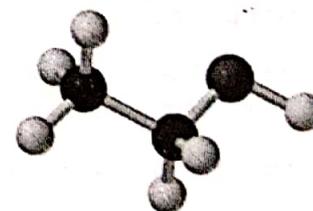


a tertiary alcohol

The common name of an alcohol is obtained by citing the name of the alkyl group to which the OH group is attached, followed by the word "alcohol."

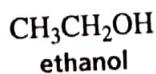


methyl alcohol

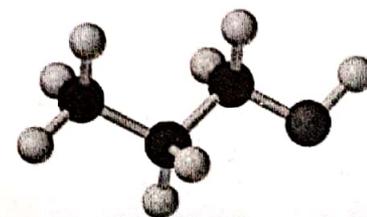


ethyl alcohol

The **functional group** is the center of reactivity in a molecule. In an alcohol molecule, the OH is the functional group. The IUPAC system uses a suffix to denote certain functional groups. The systematic name of an alcohol, for example, is obtained by replacing the "e" at the end of the name of the parent hydrocarbon with the suffix "ol."

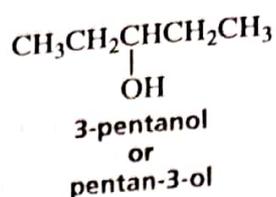


When necessary, the position of the functional group is indicated by a number immediately preceding the name of the alcohol, or immediately preceding the suffix. The most recently approved IUPAC names are those with the number immediately preceding the suffix. However, names with the number preceding the name of the alcohol have been in use for a long time, so those are the ones most likely to



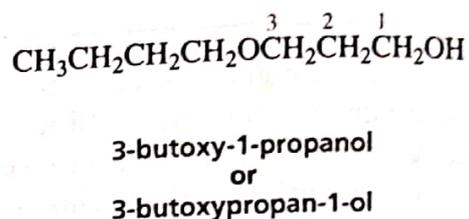
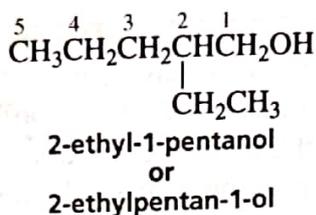
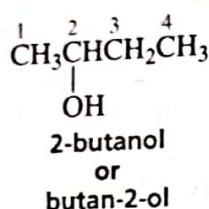
propyl alcohol

appear in the literature, on reagent bottles, and on standardized tests. Those will also appear most often in this book.



Use the following rules when naming a compound that has a functional group suffix:

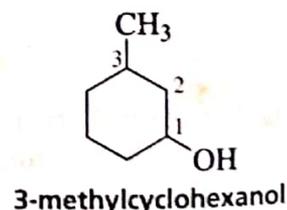
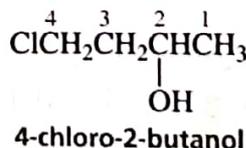
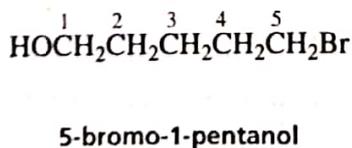
1. The parent hydrocarbon is the longest continuous chain *containing the functional group*.
2. The parent hydrocarbon is numbered in the direction that gives the *functional group suffix the lowest possible number*.



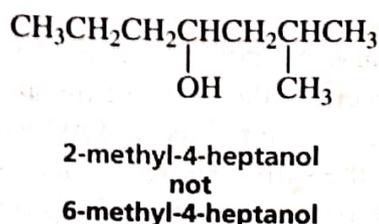
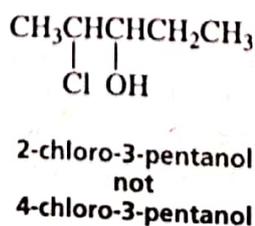
The longest continuous chain has six carbons, but the longest continuous chain containing the OH functional group has five carbons so the compound is named as a pentanol.

The longest continuous chain has four carbons, but the longest continuous chain containing the OH functional group has three carbons, so the compound is named as a propanol.

3. If there is a functional group suffix and a substituent, the functional group suffix gets the lowest possible number. Notice that a number is not needed to designate the position of a functional group suffix in a cyclic compound because it is assumed to be at the 1-position.



4. If the same number for the functional group suffix is obtained in both directions, the chain is numbered in the direction that gives a substituent the lowest possible number.



- c. a ten-carbon compound with one  $\pi$  bond and two rings  
 d. an eight-carbon compound with three  $\pi$  bonds and one ring

**SOLUTION TO 1a** For a five-carbon hydrocarbon with no  $\pi$  bonds and no rings,  $C_nH_{2n+2} = C_5H_{12}$ ; a five-carbon hydrocarbon with  $(\pi + r) = 2$ , has four fewer hydrogens because two hydrogens are subtracted for every  $\pi$  bond or ring present in the compound. Therefore, its molecular formula is  $C_5H_8$ .

### PROBLEM 2 / SOLVED

Determine  $(\pi + r)$  for the hydrocarbons with the following molecular formulas:

- a.  $C_{10}H_{16}$                       b.  $C_{20}H_{34}$                       c.  $C_8H_{16}$                       d.  $C_{12}H_{20}$

**SOLUTION TO 2a** For a ten-carbon hydrocarbon with no  $\pi$  bonds and no rings,  $C_nH_{2n+2} = C_{10}H_{22}$ . Thus, a ten-carbon compound with molecular formula  $C_{10}H_{16}$  has six fewer hydrogens. Therefore,  $(\pi + r) = 3$ .

### PROBLEM 3

Draw possible structures for compounds with the following molecular formulas:

- a.  $C_3H_6$                       b.  $C_3H_4$                       c.  $C_4H_6$

The systematic (IUPAC) name of an alkene is obtained by replacing the “ane” ending of the alkane with “ene.” For example, a two-carbon alkene is called ethene and a three-carbon alkene is called propene. Ethene is frequently referred to by its common name (ethylene).

## 3.2 NOMENCLATURE OF ALKENES

systematic name:  $H_2C=CH_2$   
 common name: ethene  
 ethylene

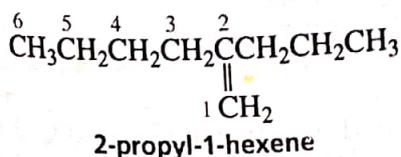
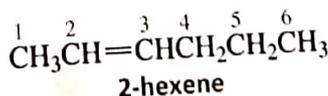
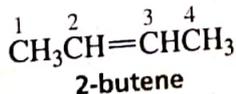
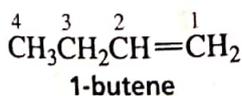
$CH_3CH=CH_2$   
 propene  
 propylene

  
 cyclopentene

  
 cyclohexene

Most alkene names need a number to indicate the position of the double bond. (The previous names do not because there is no ambiguity.) The same IUPAC rules we learned in Chapter 2 are followed in naming alkenes.

- The longest continuous chain containing the functional group (in this case, the carbon-carbon double bond) is numbered in a direction that gives the functional group suffix the lowest possible number. For example, 1-butene signifies that the double bond is between the first and second carbons of butene; 2-hexene signifies that the double bond is between the second and third carbons of hexene.

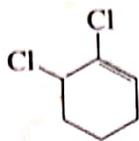


the longest continuous chain has eight carbons but the longest continuous chain containing the functional group has six carbons, so the parent name of the compound is hexene

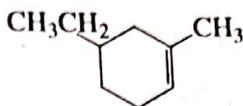
Notice that 1-butene does not have a common name. You might be tempted to call it “butylene,” which is analogous to “propylene” for propene, but



sum of the substituent numbers. For example, 1,6-dichlorocyclohexene is not called 2,3-dichlorocyclohexene even though the latter has the lowest sum of the substituent numbers ( $1 + 6 = 7$  versus  $2 + 3 = 5$ ); 1,6-dichlorocyclohexene is the correct name because it has the lowest substituent number (1).

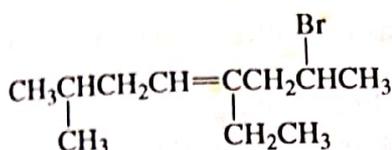


1,6-dichlorocyclohexene  
not  
2,3-dichlorocyclohexene  
because  $1 < 2$

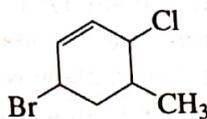


5-ethyl-1-methylcyclohexene  
not  
4-ethyl-2-methylcyclohexene  
because  $1 < 2$

6. If both directions lead to the same number for the alkene functional group suffix and the same low number(s) for one or more of the substituents, then those substituents are ignored and the direction is chosen that gives the lowest number to one of the remaining substituents.

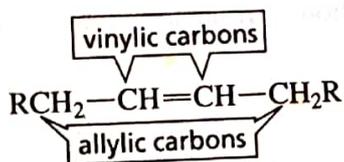


2-bromo-4-ethyl-7-methyl-4-octene  
not  
7-bromo-5-ethyl-2-methyl-4-octene  
because  $4 < 5$



6-bromo-3-chloro-4-methylcyclohexene  
not  
3-bromo-6-chloro-5-methylcyclohexene  
because  $4 < 5$

The  $sp^2$  carbons of an alkene are called **vinyllic carbons**. An  $sp^3$  carbon that is adjacent to a vinyllic carbon is called an **allylic carbon**.



There are two groups that contain a carbon-carbon double bond that are used as substituent groups in common names—the **vinyl group** and the **allyl group**. The vinyl group is the smallest possible group that contains a vinyllic carbon, and the allyl group is the smallest possible group that contains an allylic carbon. When allyl is used in nomenclature, the substituent must be attached to the allylic carbon.

systematic name:  $H_2C=CH-$   
common name: the vinyl group

systematic name:  $H_2C=CHCl$   
common name: chloroethene  
vinyl chloride

systematic name:  $H_2C=CHCH_2-$   
common name: the allyl group

systematic name:  $H_2C=CHCH_2Br$   
common name: 3-bromopropene  
allyl bromide



Tutorial: Common names of alkyl groups

### PROBLEM 4 ♦

Draw the structure for each of the following compounds.

a. 3,3-dimethylcyclopentene

c. ethyl vinyl ether

b. 6-bromo-2,3-dimethyl-2-hexene

d. allyl alcohol

Acetylene ( $\text{HC}\equiv\text{CH}$ ), the common name for the smallest alkyne, may be a familiar word to you because of the oxyacetylene torch used in welding. Acetylene is supplied to the torch from one high-pressure gas tank and oxygen is supplied from another. Burning acetylene produces a high-temperature flame capable of melting and vaporizing iron and steel.

### PROBLEM 1

What is the molecular formula for a cyclic alkyne with 14 carbons and 2 triple bonds?

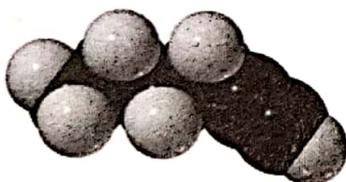
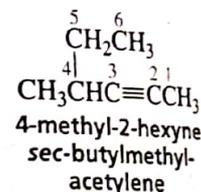
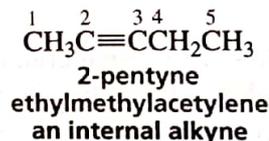
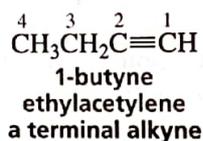
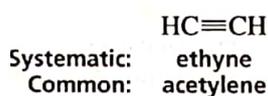
## 5.1 NOMENCLATURE OF ALKYNES



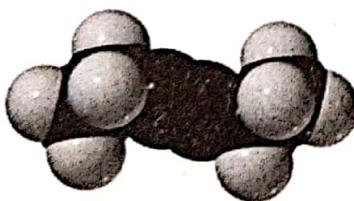
3-D Molecules:

1-Hexyne;

3-Hexyne



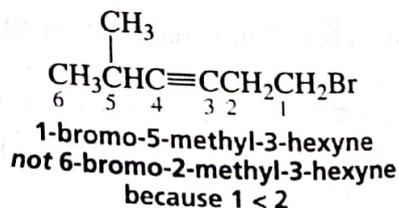
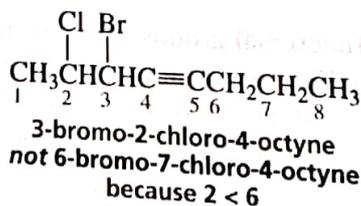
1-hexyne



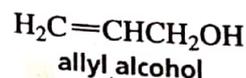
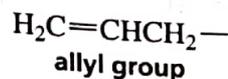
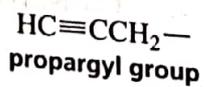
3-hexyne

In common nomenclature, alkynes are named as substituted acetylenes. The common name is obtained by naming the alkyl groups, in alphabetical order, that have replaced the hydrogens of acetylene. Acetylene is an unfortunate common name for the smallest alkyne because its "ene" ending is characteristic of a double bond rather than a triple bond.

If the same number for the alkyne functional group suffix is obtained in both directions along the carbon chain, the correct systematic name is the one that contains the lowest substituent number. If the compound contains more than one substituent, the substituents are listed in alphabetical order.



The triple-bond-containing propargyl group is used in common nomenclature. It is analogous to the double-bond-containing allyl group that you saw in Section 3.2.



A substituent receives the lowest possible number only if there is no functional group suffix, or if the same number for the functional group suffix is obtained in both directions.

**PROBLEM 2** ◆

Draw the structure for each of the following compounds.

- 1-chloro-3-hexyne
- cyclooctyne
- isopropylacetylene
- propargyl chloride
- 4,4-dimethyl-1-pentyne
- dimethylacetylene

**PROBLEM 3** ◆

Give the systematic name for each of the following compounds.

- $\text{BrCH}_2\text{CH}_2\text{C}\equiv\text{CCH}_3$
- $\text{CH}_3\text{CH}_2\underset{\text{Br}}{\text{CH}}\text{C}\equiv\text{CCH}_2\underset{\text{Cl}}{\text{CH}}\text{CH}_3$
- $\text{CH}_3\text{OCH}_2\text{C}\equiv\text{CCH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}_2\underset{\text{CH}_2\text{CH}_2\text{CH}_3}{\text{CH}}\text{C}\equiv\text{CH}$

**PROBLEM 4** ◆

Draw the structures and give the common and systematic names for the seven alkynes with molecular formula  $\text{C}_6\text{H}_{10}$ .

**PROBLEM 5**

Which would you expect to be more stable, an internal alkyne or a terminal alkyne? Why?

All hydrocarbons have similar physical properties. In other words, alkenes and alkynes have physical properties similar to those of alkanes (Section 2.9). All are insoluble in water and all are soluble in solvents with low polarity such as benzene and ether. They are less dense than water and, like other homologous series, have boiling points that increase with increasing molecular weight (Table 5.1). Alkynes are more linear than alkenes, and a triple bond is more polarizable than a double bond

## 5.2 PHYSICAL PROPERTIES OF UNSATURATED HYDROCARBONS

**TABLE 5.1 Boiling Points of the Smallest Hydrocarbons**

	bp (°C)		bp (°C)		bp (°C)
$\text{CH}_3\text{CH}_3$	-88.6	$\text{H}_2\text{C}=\text{CH}_2$	-104	$\text{HC}\equiv\text{CH}$	-84
ethane		ethene		ethyne	
$\text{CH}_3\text{CH}_2\text{CH}_3$	-42.1	$\text{CH}_3\text{CH}=\text{CH}_2$	-47	$\text{CH}_3\text{C}\equiv\text{CH}$	-23
propane		propene		propyne	
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	-0.5	$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$	-6.5	$\text{CH}_3\text{CH}_2\text{C}\equiv\text{CH}$	8
butane		1-butene		1-butyne	
$\text{CH}_3(\text{CH}_2)_3\text{CH}_3$	36.1	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$	30	$\text{CH}_3\text{CH}_2\text{CH}_2\text{C}\equiv\text{CH}$	39
pentane		1-pentene		1-pentyne	
$\text{CH}_3(\text{CH}_2)_4\text{CH}_3$	68.7	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$	63.5	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{C}\equiv\text{CH}$	71
hexane		1-hexene		1-hexyne	
		$\text{CH}_3\text{CH}=\text{CHCH}_3$	3.7	$\text{CH}_3\text{C}\equiv\text{CCH}_3$	27
		<i>cis</i> -2-butene		2-butyne	
		$\text{CH}_3\text{CH}=\text{CHCH}_3$	0.9	$\text{CH}_3\text{CH}_2\text{C}\equiv\text{CCH}_3$	55
		<i>trans</i> -2-butene		2-pentyne	