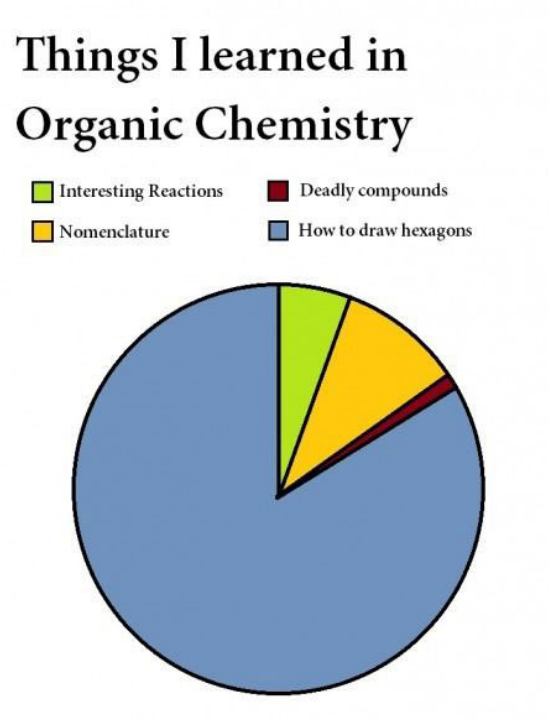
Chemistry 11

Organic Chemistry



Name:_____ **Block:**_____

8.1 Simple Hydrocarbons and Isomerism

Warm Up

1. Draw the Lewis dot structure for carbon.

2. How many valence electrons does a carbon atom have? _____

3. Classify the following compounds as ionic or covalent:
   (a) Na_2CO_3 _____
   (b) C_2H_6 _____
   (c) CO_2 _____
   (d) CaC_2 _____
   (e) C_2H_5OH _____

Organic Compounds

Chemical compounds can be classified as belonging to one of two very large groups:
_____ or
i_____compounds.
Organic compounds contain _____atoms, usually bonded to other carbon atoms and _____atoms. They may also contain other elements such as halogens, nitrogen, oxygen, phosphorus, and sulphur.

Note that some compounds such as carbonates, carbides, and oxides of carbon contain carbon but are not classified as organic compounds. For example, in the question 3 above, C_2H_6 and C_2H_5OH are organic.
The remaining compounds in question 3 are inorganic: Na_2CO_3, CO_2, and CaC_2.

Chemists have been distinguishing organic and inorganic compounds for hundreds of years.

Organic compounds were called "organic" because it was believed that these compounds could only be made from l_____ such as plants or animals. Scientists thought that organic compounds contained a "life force" or "vitality."

Friedrich Wohler proved that this belief was inaccurate in 1828 when he heated an inorganic salt, ammonium cyanate [$NH_4(NCO)$] and produced urea [$(NH_2)_2CO$], an organic compound (Figure 8.1.1). Urea is a waste product of protein metabolism and, up to that time, was thought to be produced only from living things.

ammonium cyanate **urea**

Figure 8.1.1 *Heating ammonium cyanate produces urea.*

Once scientists learned that organic compounds could be made in the lab, a whole new branch of chemistry was born: **organic chemistry**. Even though we now know that not all organic compounds come from living organisms, we still use the word "organic" to describe many carbon compounds.

Introduction to Carbon Compounds

- All substances can be classified as being either _____or *inorganic*.
- Our study of chemistry will deal mainly with _____ compounds.
- Originally, organic substances were considered to be those _____ compounds that were extracted from _____ things, while inorganic ones were compounds that _____originate in living systems.

An organic compound is defined as _____.

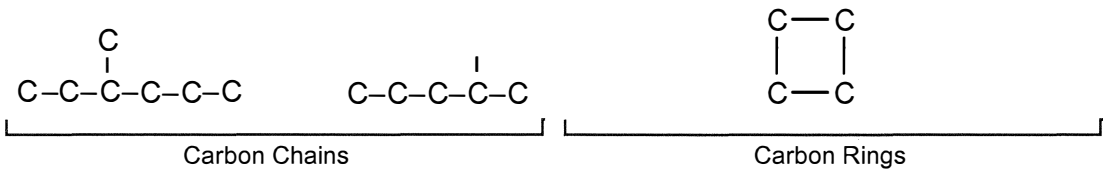
However, some compounds that contain carbon are considered to be inorganic.

A **better definition** may be that organic compounds have a _____, that carbon is the "backbone" of the compounds.

Organic chemistry plays a very important role in our daily lives. Many of the clothes we wear are made of rayon, dacron, nylon and orlon. These are all _____(man-made) organic compounds. Plastics of all sorts are synthetic organic compounds, too. Petroleum is a naturally occurring organic substance, but synthetic rubber and plastics are two of the by-products of petroleum.

A large number of modern chemical materials have been developed from by-products of petroleum. In addition to these items, other materials such as sulfa drugs, penicillin, cortisone, perfumes, detergents, vitamins, pesticides, anesthetics, and many of the more modern antibiotics are among the contributions made to society through a study of organic chemistry.

Why are there so many organic compounds? Well, carbon atoms can attach themselves to each other in wide variety of ways. They can join together to form short or long chains, and they can form rings of many kinds, as well:



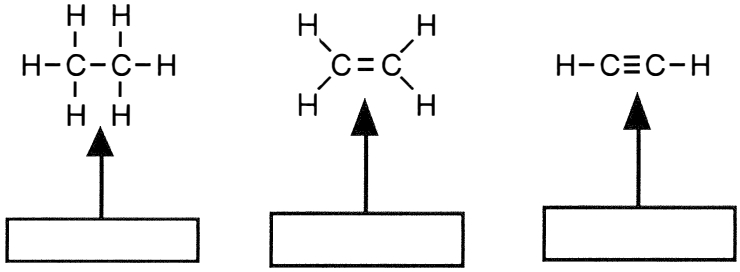
The chains and rings can have branches and cross-links with atoms of other elements (mainly _____) attached to the carbon atoms. Different arrangements of carbon atoms correspond to _____, and each compound has its own characteristic _____.

We are going to approach the subject of organic chemistry in terms of organic nomenclature. Nomenclature involves the _____.

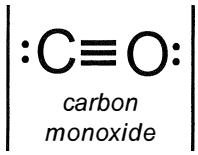
You will be given a set of rules to follow as you name compounds. **These rules must be followed very carefully.** Success in learning organic nomenclature will involve some memorization on your part, but it will rely mainly on a logical approach to the problems presented.

The second most abundant element found in organic compounds is _____
To start, we will deal exclusively with compounds composed of only carbon and hydrogen.
These are called _____. These two elements can combine in countless ways.

The structures of some hydrocarbons are shown below. The lines between the atomic symbols represent bonds. There are three types of carbon to carbon bonds:



In each case you will note that carbon has a total of _____bonds.
This is because carbon has four _____.
There are only a few carbon compounds in which carbon does not have four bonds.
One example is _____.



carbon monoxide

With so many different ways that carbon can bond, there are millions of known organic compounds. Every day, you use organic products such as foods, cosmetics, plastics, clothing fibres, pharmaceuticals, and fuels.

Sample Problem — Using Structural Formulas to Represent Organic Compounds

Butane is a fuel used in lighters. It has the formula C_4H_{10} and has four carbon atoms attached to each other in a chain with only single bonds. Draw a structural formula for butane.

What to Think about

1. The four carbon atoms are bonded to each other in a chain, so draw four carbon atoms attached to one another in a line.
2. Each carbon atom can form four covalent bonds. The first carbon atom has one bond to the carbon atom beside it. It can therefore bond with three hydrogen atoms.
3. The next two carbon atoms have two other carbon atoms already covalently bonded to them. They can only bond with two hydrogen atoms each.
4. The last carbon atom is already bonded to one other carbon atom. It can form three bonds with hydrogen. The formula shown on the right is called a structural formula.
5. Condense this structural formula by writing the number of hydrogen atoms bonded to each carbon.
6. To condense this formula even more, use a line to represent each carbon bond. Do not show the carbon or hydrogen atoms at all. Notice that the lines will not be attached in a straight line. Organic molecules are not linear. At the end of each line segment is a carbon atom not shown. Hydrogen atoms are also not shown in this formula.

How to Do It

Structural Formula:

Condensed Structural Formula:

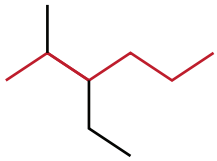
Carbon Skeleton Formula:

Practice Problems 1—Using Structural Formulas to Represent Organic Compounds

1. Octane, a constituent of gasoline, has the molecular formula C_8H_{18}. Draw a structural formula, condensed structural formula, and carbon skeletal formula for octane. Assume that the carbons are all bonded in a single chain to each other.

2. Draw a structural formula, condensed structural formula, and carbon skeletal formula for C_6H_{12}. Arrange the carbon atoms in a closed ring shape so that each carbon atom is bonded to two other carbon atoms.

3. The carbon skeleton formula for an organic compound is shown below. Draw the structural and condensed structural formula. What is its molecular formula?



Hydrocarbons

Hydrocarbons are the simplest types of organic compounds.

_____are compounds that contain only carbon and hydrogen atoms.

We will examine five types of hydrocarbons:

_____, _____, _____, _____, and aromatic hydrocarbons.

The _____family represents the simplest of the hydrocarbons.

The general formula for the compounds in this family is _____, where "n" equals the number of carbon atoms in the molecule.

Table 8.1.1 *Greek Prefixes*

No. of C Atoms	Prefix
1	*meth-*
2	*eth-*
3	*prop-*
4	*but-*
5	*pent-*
6	*hex-*
7	*hept-*
8	*oct-*
9	*non-*
10	*dec-*

Problem 1. Give the name and molecular formula for each compound below. Use the formula C_nH_{2n+2} to determine the formula, and add the suffix "ane" to the prefixes to obtain the names.

	Prefix	*No. of Carbons*	*Name*	*Molecular Formula*
a.	meth	1	methane	CH_4
b.	-eth-	2	_____	_____
c.	prop	3	_____	C_3H_8
d.	-but-	4	_____	_____
e.	pent	5	pentane	_____
f.	-hex-	6	_____	_____
g.	hept-	7	_____	_____
h.	oct-	8	_____	_____
i.	non-	9	_____	_____
j.	dec-	10	_____	$C_{10}H_{22}$

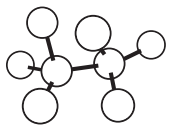
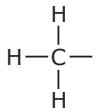
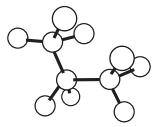
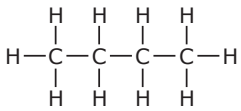
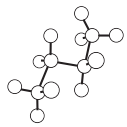
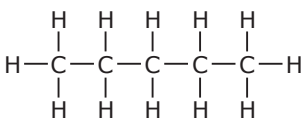
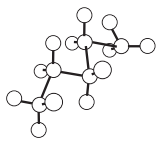
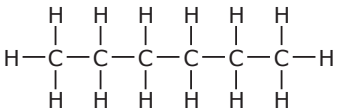
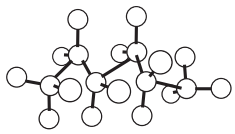
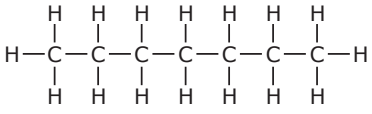
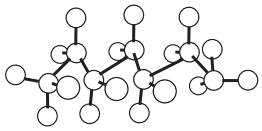
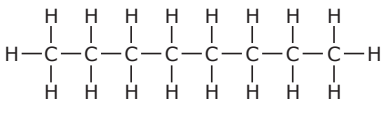
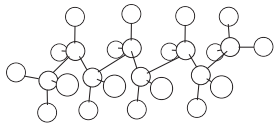
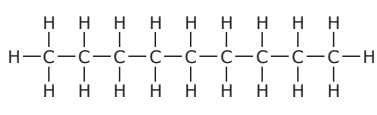
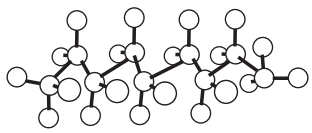
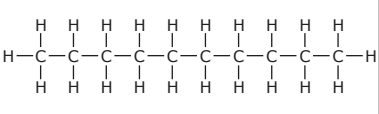
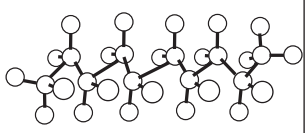
The Alkanes

The compounds in the alkane family are often called *saturated* compounds, which means that the molecules contain only _____bonds between the carbon atoms. "Saturated" also describes that there is no room for other atoms to bond to the carbon skeleton.

Naming alkanes is fairly simple. The _____in the name of each compound indicates the _____ _____ atoms present.

All alkanes have a suffix of -_____ To make writing formulas or drawing structures easier, the hydrogens on the carbons are not always shown, however, you should assume that enough hydrogen atoms are present to give each carbon atom 4 bonds.

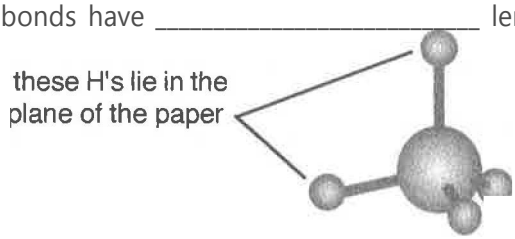
Table 8.1.2 *10 Straight-Chain Alkanes You Need to Know*

Name	Molecular formula	Structural formula	Ball and stick model	Condensed Structural Formula & Carbon Skeleton
*meth*ane				
	C_2H_6			
				
				
				
				
				
				
				
				

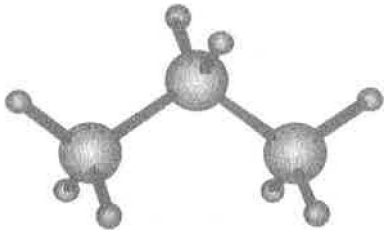
THE GEOMETRY OF ALKANES

Although the bonds on a carbon atom are usually drawn as if they were run over by a steam roller, lying flat on a page at right angles to each other, the bonds are actually arranged in the shape of a 4-cornered pyramid (a "TETRAHEDRON") as shown below.

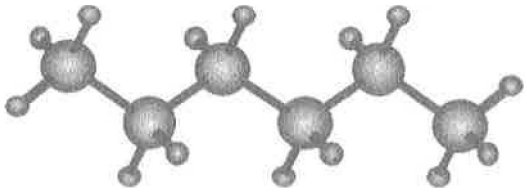
All the bonds have _____ lengths and all the H-C-H angles are _____



Therefore the actual shape of the propane molecule can be shown as

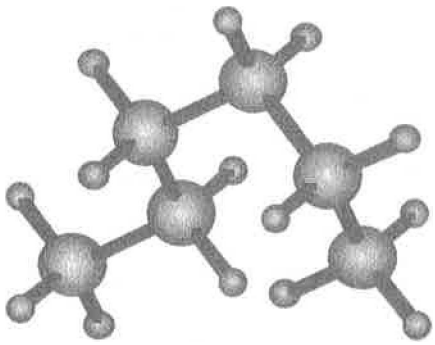


and a molecule of hexane might look something like the following.



Each of the single bonds between the carbon atoms is able to r_____freely, leading to a highly_____chain which can wave about and take many shapes.

The above arrangement is one shape _____can assume; another might be the arrangement shown below.



NOTICE: An **ALKYL GROUP** is an alkane which has lost one hydrogen atom. *(more on this later)*

$CH_4 \xrightarrow{\text{remove one H}}$

$CH_3{-}CH_3 \xrightarrow{\text{remove one H}} CH_3{-}CH_2{-}$

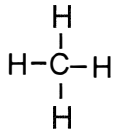
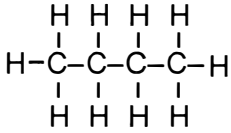
$CH_3{-}CH_2{-}CH_3 \xrightarrow{\text{remove one H}}$ $CH_3{-}CH_2{-}CH_2{-}$ (remove end H) or $CH_3{-}\underset{\displaystyle H}{\underset{|}{C}}{-}CH_3$ (remove middle H)

Chemistry Shorthand

Writing structural formulas for organic compounds can become very cumbersome when all of the chemical bonds are included in the drawings.

Instead, chemists write a *condensed* _____ where the carbon atoms are still written separately, but the hydrogens which are bound to carbons are not. Instead, the hydrogens are written to the right of the carbon atoms to which they are bonded.

Examples:

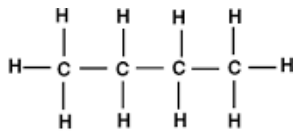
Compound	*Molecular Formula*	*Structural Formula*	*Condensed Structural Formula*
methane	CH_4		CH_4
butane	C_4H_{10}		$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$

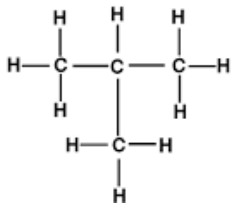
Practice Problem 2. Complete the exercise below.

Compound Name	*Molecular Formula*	*Condensed Structural Formula*
a. methane	_____CH_4_____	_____CH_4_____
b. ethane	_____	_____
c. propane	_____	_____
d. butane	_____C_4H_{10}_____	_____$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$_____
e. pentane	_____	_____
f. hexane	_____	_____
g. heptane	_____	_____
h. octane	_____	_____
i. nonane	_____	_____
j. decane	_____	_____

Naming Branched Alkanes

Not only do carbon atoms bond together to make chains, but often _____ of carbon atoms are connected to the carbon atoms of the main chain. These branches are called _____groups.

butane 

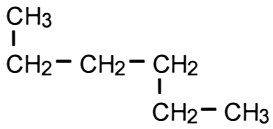
iso-butane 

Branched Alkanes: Alkyl Groups

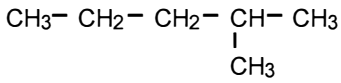
Carbon chains are _____ structures. They can bend and flex freely. When we say that an _____has a "_____" chain, we don't really mean straight. We mean that it is a _____ chain, rather than a *branched chain*.

The two structures below both contain **six carbon atoms**.

The one on the left is "straight," while the one on the right is branched.



This is one continuous chain of carbon atoms.



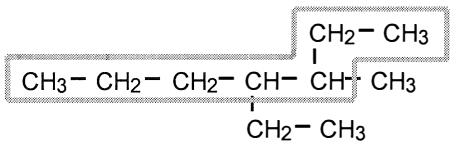
This is a branched chain of carbon atoms.

Most alkanes exist as **"branched" molecules** such as the one shown below.

The _____chain of carbon atoms in the molecule below is _____(enclosed by box).

Therefore, the parent compound here is _____.

(Remember, the longest continuous chain is not necessarily straight!)



The longest continuous chain contains 7 carbon's.

Having identified the parent compound, we must next identify the *side chains,* commonly called _____*groups*. Alkyl groups are _____to the longest continuous chain.

When written alone, they are usually shown with a free-bonding site represented by a dash *(like this: –CH_3).*

This bonding site represents a spot where a _____atom has been removed and an *alkyl group* can attach/bond. The general formula for the alkyl groups is C_nH_{2n+1}.

Alkyl groups are named with the **same prefixes** as the alkanes themselves.

The suffix is changed from "ane" to "_____"

Practice Problem 3.
Complete the exercise :

Enter the formulas and condensed structural formulas of the first six alkyl groups.

	Name of Alkyl group	Condensed Structural Formula
a.	methyl	–CH_3
b.		
c.		
d.	butyl	–CH_2–CH_2–CH_2–CH_3
e.		
f.		

Rules for Naming Branched Alkanes:

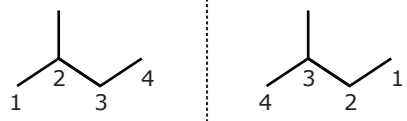
1. Find the_____of carbon atoms. It does not have to be in a straight line. This is the "parent" chain. State the number of carbon atoms using the appropriate prefix and the ending "ane."

2. _____atoms in the parent chain starting at the end _____ to the branches. Branches are called "alkyl" groups. The carbon atom's number becomes like the "address" of the branch off the parent chain.

3. Name each _____with a prefix according to the number of carbon atoms it contains. Branch names end in "_____" instead of "ane."
   *For example, a branch containing one carbon atom is called a _____**yl** branch. If the branch contains two carbon atoms, it is called an _____**yl** branch.*
   List the branches in _____order. Then, if two, three, or four branches have the same number of carbon atoms, use the prefixes "di" (two),
   "tri" (three), and tetra" (four). For example, if there are two branches each with three carbons, they are called "dipropyl."

4. State the name of the alkane by first listing the "address" of each branch, then naming the branches, then naming the parent. Use commas between numbers and hyphens between a number and a branch name.

   Figure 8.1.2 shows an example of a branched alkane correctly named and incorrectly named.
   Which is correct and which is incorrect?
   Note that the carbon atoms in the parent chain must be numbered starting at the end closest to the branch.

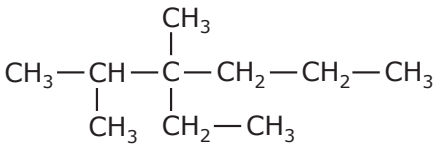


2-methyl butane **3-methyl butane**

Figure 8.1.2 *Example of how to name a branched alkane*

Sample Problem — Naming Simple Alkanes

Name the simple alkane shown here.



What to Think about

1. The longest chain of carbon atoms is six and the prefix for six is "hex." Name the parent chain.

2. The parent chain carbons are numbered from the left, because the branches start closer to the left. The branch addresses from left to right would be 2, 3, 3. There is a methyl group attached to the second and also the third carbon atom in the parent chain.

3. There is an ethyl group attached to the third carbon in the parent chain.

4. The name states the address then the branch names alphabetically, then the parent chain. Alphabetically, "ethyl" will be listed before "methyl." We do not consider the prefixes "di" and "tri" etc. when listing alphabetically.

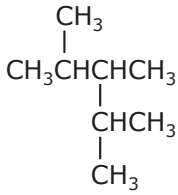
How to Do It

Practice Problems - Naming Simple Alkanes

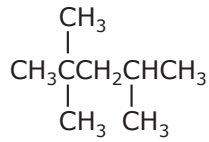
Name the following alkanes:

1. (a) _____

   (b) _____



(a)

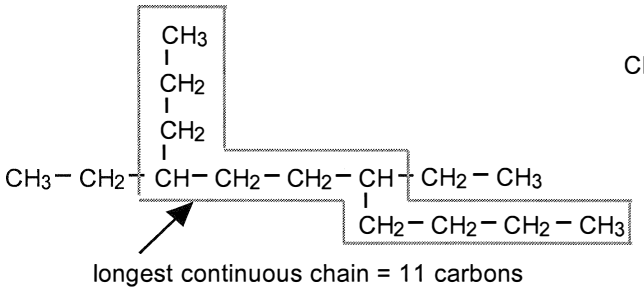


(b)

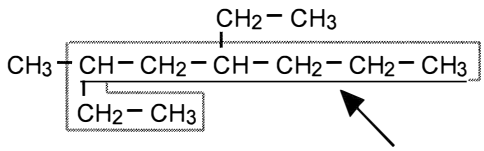
2. Draw the condensed structural formula for 4-ethyl-2,3-dimethyl-5-propyloctane.

3. Draw the condensed structural formula for 3,4,4,5- tetramethyldecane.

Name the following hydrocarbon chains:



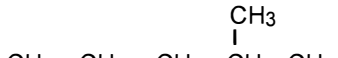
longest continuous chain = 11 carbons

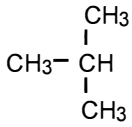


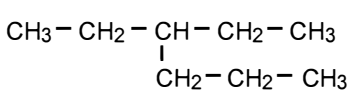
longest continuous chain = 8 carbons

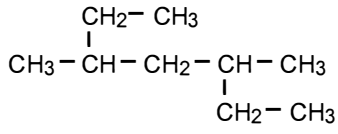
RULE 1: Locate the longest continuous chain of carbon atoms. This will give you the name of the "parent" compound

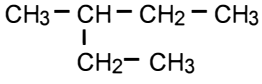
Problem 4. Draw a box around the longest continuous chain of carbon atoms in the structures below, and name the parent compound for each one.

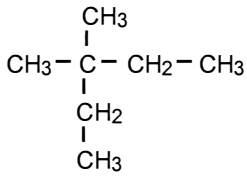
a. 

b. 

c. 

d. 

e. 

f. 

a. parent: _____

b. parent: _____

c. parent: _____

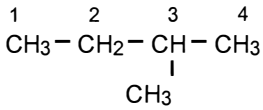
d. parent: _____

e. parent: _____

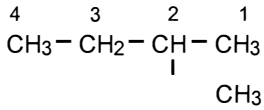
f. parent: _____

RULE 2: The name of the parent compound is modified by noting what alkyl groups are attached to the chain. Number the longest chain so that the alkyl group(s) will be on the lowest numbered carbons.

Note in the molecules shown below, that the longest chain should be numbered from right to left in order to give the carbon which is bonded to the methyl group the lowest possible number:



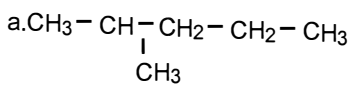
Incorrect Numbering



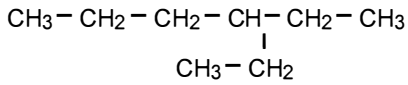
Correct Numbering

The correct name of this compound is 2-methylbutane. The "2-" indicates that the methyl group is attached to the second carbon in the longest chain. Note that the name of the alkyl group is added to that of the parent compound (butane) to form one word, and that hyphens are used to separate numbers from alphabetical parts of the name.

Problem 5. For the following compounds, draw a box around the longest continuous carbon chain and name each molecule. The name of the molecule in part "b" is given to help you.

a. 

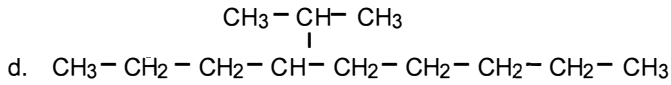
Name: _____

b. 

Name: 3-ethylhexane

c. 

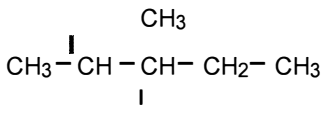
Name: _____

d. 

Name: _____

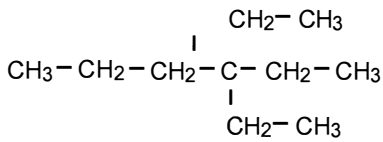
RULE 3: When the same alkyl group occurs more than once in a molecule, the numbers of the carbons to which they are attached are all included in the name. The number of the carbon is repeated as many times as the group appears. The number of repeating alkyl groups is indicated in the name by the use of Greek prefixes for 2, 3, 4, 5, etc. (di, tri, tetra, penta, etc.).

To better understand rule 3, study the following examples.



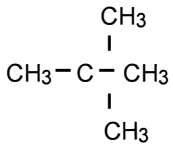
is called 2,3-dimethylpentane

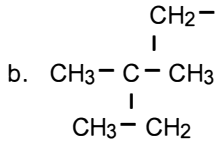
Note that numbers used in the name are separated from each other by commas, and note that the numbers are separated from the rest of the name with a hyphen.

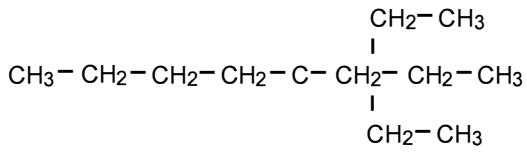


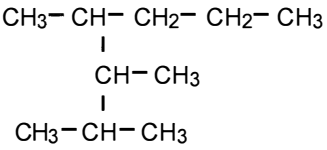
is called 3,3-diethylhexane

Problem 6. Name the four molecules whose structures are drawn below.

a. 

b. 

c. 

d. 

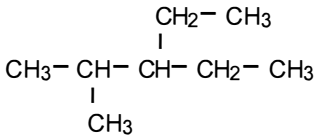
a. _____

b. _____

c. _____

d. _____

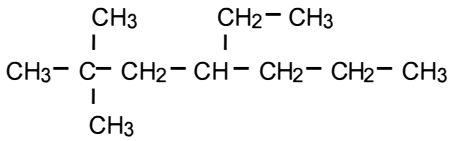
RULE 4: If there are two or more different kinds of alkyl groups attached to the parent chain, name them in alphabetical order.

For example: 

is called 3-ethyl-2-methylpentane

It is NOT called 2-methyl-3-ethylpentane

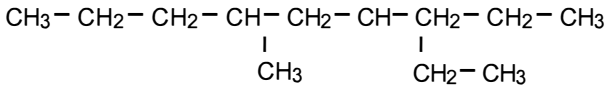
However, when you are determining the alphabetical order, do not consider any Greek prefixes that are being used. For example:



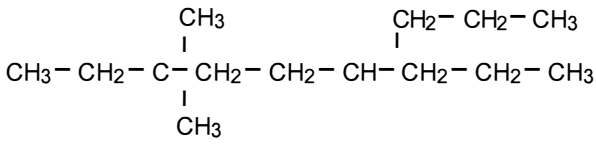
is called 4-ethyl-2,2-dimethylheptane

It is NOT called 2,2-dimethyl-4-ethylheptane

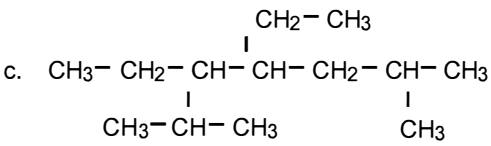
Problem 7. Name the four molecules drawn below.

a. 

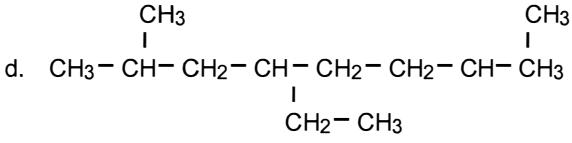
_____

b. 

_____

c. 

_____

d. 

_____

RULE 5: To put the finishing touches on the name of an alkane, keep the following points in mind: (a) hyphens are used to separate numbers from names of substituents; (b) numbers are separated from each other by commas; (c) the last alkyl group to be named is prefixed to the name of the parent alkane, forming one word; and (d) the suffix "-ane" indicates that the molecule is an alkane.

Using Molecular Models

The structure of alkanes is more understandable if you see them in three dimensions.
We will use **molecular model kits** for this purpose.

Obtain a box containing a molecular model kit and determine which parts represent carbon atoms, hydrogen atoms, carbon to carbon bonds, and carbon to hydrogen bonds. *(draw these below)*

Hydrogen: Carbon: Carbon– Hydrogen bonds: Carbon– Carbon bonds:

When you have done this, **assemble models of the six molecules drawn in Problem 4.**

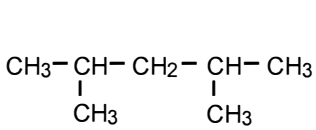
Pick up one of your models and rotate one section of the model while holding the other.
Do you see how rotation is possible around a single bond? _____ .

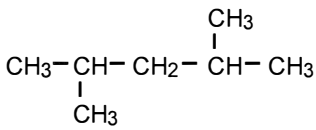
Holding the model with both hands, bend and flex it a bit. Note the bond angles between the carbons themselves and between the carbons and the hydrogens.
Do you see why these molecules are not really "straight" chains? _____

Because free rotation is possible around a single bond, what can you conclude about the 2 molecules shown below?(1_____

If you named these two molecules, what would you discover?{2,_____

What is the name?{3,_____





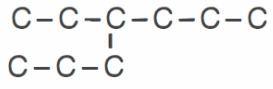
Practice Questions

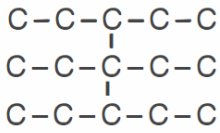
1. Look at the sequence of hydrogen atoms connected to carbon atoms in the list below.

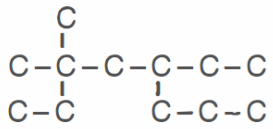
   CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, etc.

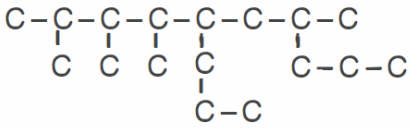
   Suggest a general formula for all straight–chain alkanes. That is, if there are "N" carbons, how many hydrogens will be present?

2. Determine the number of carbon atoms in the longest chain of each of the following, and name the parent hydrocarbon represented by the longest chain.

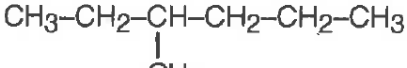
   (a) 

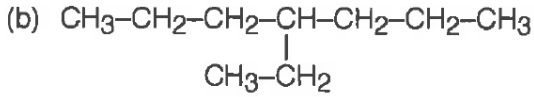
   (b) 

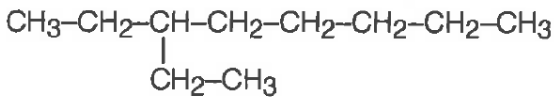
   (c) 

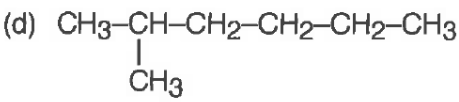
   (d) 

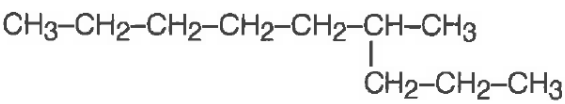
3. Name the following hydrocarbons. Care: e and f are tricky!

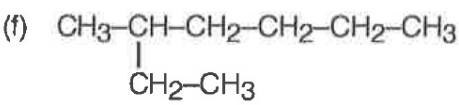
   (a) 

   (b) 

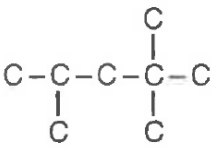
   (c) 

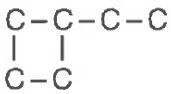
   (d) 

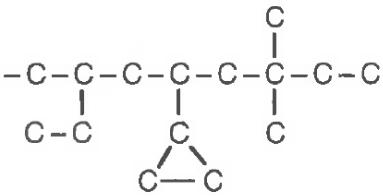
   (e) 

   (f) 

4. Re–write the following structures to show the hydrogens attached.

   (a) 

   (b) 

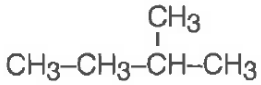
   (c) 

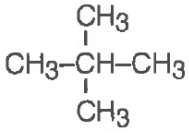
5. Draw the following hydrocarbons. Include all hydrogens.
   (a) 3–methylhexane
   (b) 4–ethyloctane
   (c) 2–methylpentane
   (d) 4–propylnonane
   (e) 3–ethylheptane
   (f) 5–propyldecane

6. What is wrong with each of the following? (You may have to sketch the molecule to see the error in some cases.)

   (a) 6–methylheptane

   (b) 1–ethylbutane

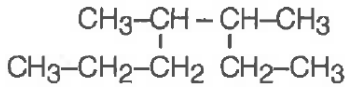
   (c) 

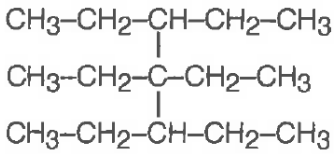
   (d) 

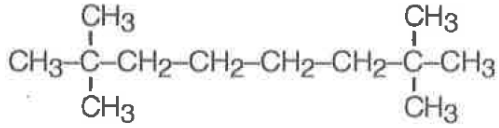
EXERCISES:

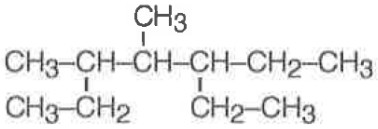
7. Count up the number of carbons and hydrogens in the two example molecules above. The general formula for a simple straight–chain hydrocarbon (methane, ethane, etc.) is C_NH_{2N+2}. What is the general formula for a branched hydrocarbon?

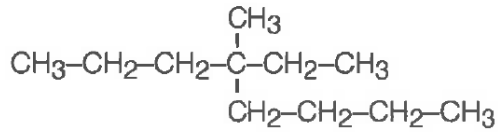
8. Name the following molecules.

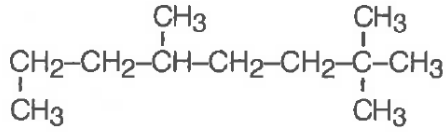
(a) 

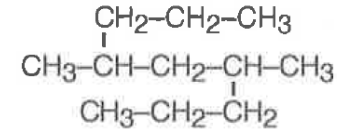
(b) 

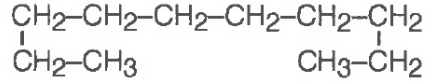
(c) 

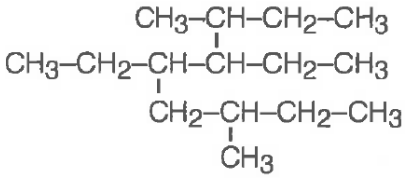
(d) 

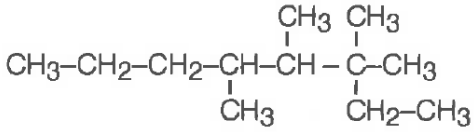
(e) 

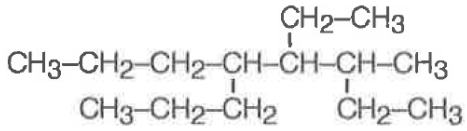
(f) 

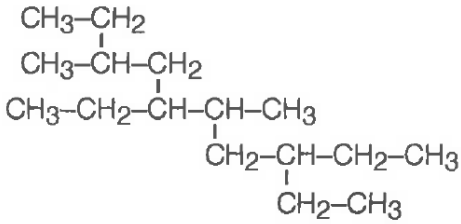
(g) 

(h) 

(i) 

(j) 

(k) 

(l) 

Complete the following Question #9 on a separate page.

9. Sketch the following molecules.
   (a) 3–ethyl–2,3–dimethylhexane
   (b) 2,2–dimethyl–5,6–dipropylnonane
   (c) 4–ethyl–3–methyl–5–propyloctane
   (d) 2,2,3,3–tetramethylpentane
   (e) 3,4–diethylhexane
   (f) 5–butyl–6,6–diethyl–3,3,7–trimethyldecane
   (g) dimethylpropane (why were no numbers used?)
   (h) 4–ethyl–2–methyloctane
   (i) hexamethylpentane
   (j) 3,6–diethyl–4–methyl–5–propyloctane

Isomers

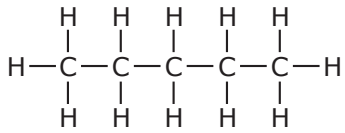
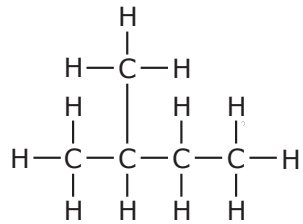
Consider Table 8.1.2 below. What do you notice about the molecular formulas of the two substances in the table?

Pentane and 2-methybutane are **different compounds** with *different chemical properties*, and yet they have the same _____formula.

These are called **structural isomers**. There is one more structural isomer of C_5H_{12}.

Can you figure it out?

Table 8.1.2 *Examples of structural isomers*

Name	Structural Formula	Molecular Formula
pentane		C_5H_{12}
2-methylbutane		C_5H_{12}

Depending on where the hydrogen atom is removed, the bonding site on some alkyl groups can change position. This would change the way in which the alkyl group bonds to the parent compound. For example, note the two alkyl groups shown below. Both are composed of three-carbon chains, but the bonding site differs:

$-CH_2-CH_2-CH_3$	$CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle \vert}{CH}}-$
propyl	isopropyl

The compound on the left below has a propyl group attached to the parent compound which is octane. The compound on the right has an isopropyl group attached to the parent compound (heptane). Note that all carbons in the molecules have four bonds.

$CH_3-CH_2-CH_2-\underset{\displaystyle CH_2}{\overset{\displaystyle \vert}{CH}}-CH_2-CH_2-CH_2-CH_3$	$CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle \vert}{CH}}-CH_3$ $CH_3-CH_2-CH_2-\underset{\displaystyle CH_2}{\overset{\displaystyle \vert}{CH}}-CH_2-CH_2-CH_2-CH_3$
Propyl group attached to an 8-carbon chain	Isopropyl group attached to an 8-carbon chain

Definition: **STRUCTURAL ISOMERS** are compounds which have the same molecular formula but a different arrangement of atoms.

EXAMPLE: C_4H_{10} can refer to either $CH_3-CH_2-CH_2-CH_3$ or $CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle \vert}{CH}}-CH_3$

Each structural isomer has a set of chemical and physical properties which differ from those of other isomers with the same chemical formula.

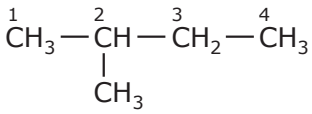
You need to be methodical when drawing **isomers** of a compound.

For example, the compound _____ has 5 carbon atoms and 12 hydrogen atoms. Let's focus on the carbon skeleton.

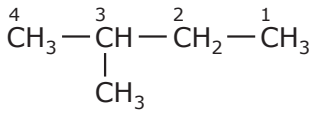
The most obvious way to arrange five carbon atoms is in a single chain:

$CH_3 — CH_2 — CH_2 — CH_2 — CH_3$

We can also arrange four carbon atoms in a chain and have the fifth carbon atom as a methyl branch.



2 - methylbutane
(Correct name)



3 - methylbutane
(Wrong name)

Figure 8.1.3 2-methylbutane

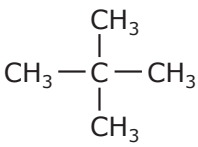
Note that the branch **cannot go on either end of the carbon chain** because then it would be a part of the parent chain, giving us pentane again.
We can put the methyl branch on the second carbon in the parent chain.

QUESTION: *Why is there not a molecule called 3-methylbutane?*

ANSWER: *It depends on numbering the carbon atoms in the parent chain. Remember to always number the carbons in the parent chain starting from the end closest to the branch. The "address" of the branches must be the lowest numbers.*

Finally, we can arrange three carbon atoms in the parent chain and have two methyl branches on the second carbon, as shown in Figure 8.1.4.

Figure 8.1.4 *2,2-dimethylpropane*



There are three structural isomers for C_5H_{12}.

As the number of carbon atoms in a molecule increases, the number of possible isomers increases dramatically.

- C_5H_{12} has _____structural isomers.
- C_6H_{14} has _____structural isomers.
- $C_{20}H_{42}$ has more than 300 000 structural isomers.

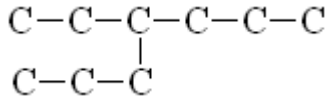
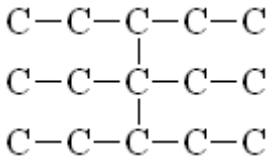
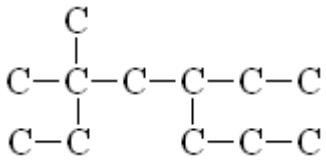
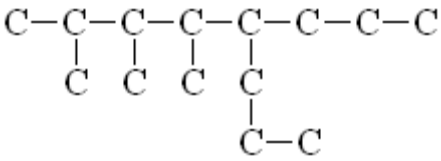
EXERCISES:

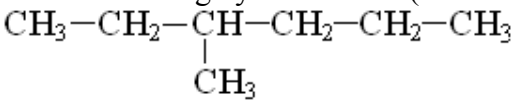
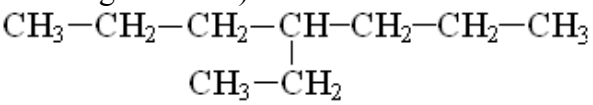
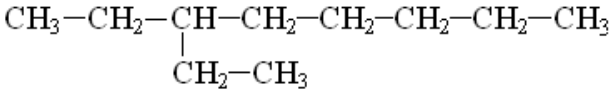
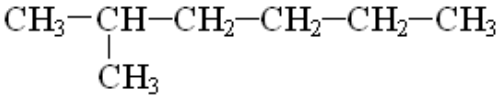
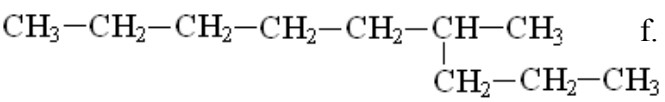
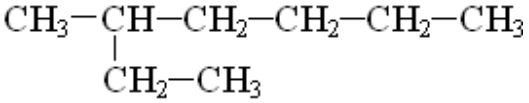
10. Write the condensed structure and name for the three structural isomers having the molecular formula C_5H_{12}.
11. Write the condensed structure and name for the two structural isomers that involve a single methyl group attached to hexane.
12. Write the condensed structure and name of the four structural isomers that involve two methyl groups attached to pentane.
13. How many isomers of C_8H_{18} contain no side chains other than a single methyl group?

Name:_____ Block:_____ Date:_____

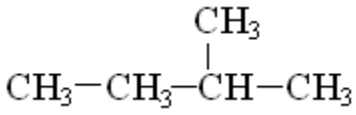
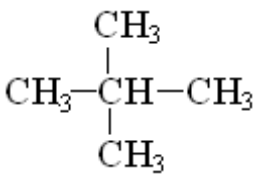
Chemistry 11 **Naming Alkanes** Assignment

Complete the following questions on a separate sheet of paper.

1. Determine the number of carbon atoms in the longest chain of each of the following, and name the parent hydrocarbon represented by the longest chain.
   a. 
   b. 
   c. 
   d. 

2. Name the following hydrocarbons. (Make sure you find the longest chain!)
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 

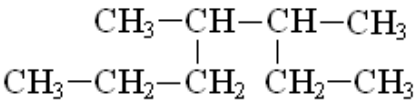
3. Draw the condensed structural formula for each of the following hydrocarbons.
   a. 3-methylhexane
   b. 4-ethyloctane
   c. 2-methylpentane
   d. 4-propylnonane
   e. 3-ethylheptane
   f. 5-propyldecane

4. Identify what is wrong with each of the following. (You may need to sketch the molecule to see the error in naming)
   a. 6-methylhexane
   b. 1-ethylbutane
   c. 
   d. 

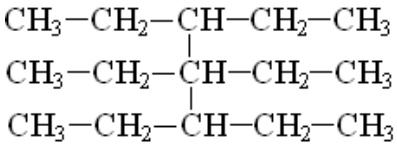
5. Draw the condensed structural formula for each of the following hydrocarbons.
   a. 3-ethyl-2,3-dimethylhexane
   b. 2,2-dimethyl-5,6-dipropylnonane
   c. 4-ethyl-3-methyl-5-propyloctane
   d. 2,2,3,3-tetramethylpentane
   e. 3,4-diethylhexane
   f. 5-butyl-6,6-diethyl-3,3,7-trimethyldecane
   g. Dimethylpropane (why are no numbers used?)
   h. 4-ethyl-2-methyloctane
   i. Hexamethylpentane
   j. 3,6-diethyl-4-methyl-5-propyloctane

6. Name the following molecules.

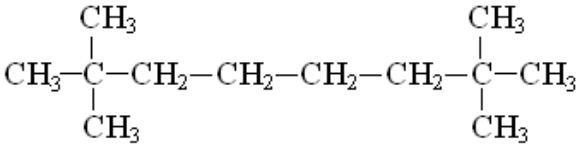
a.



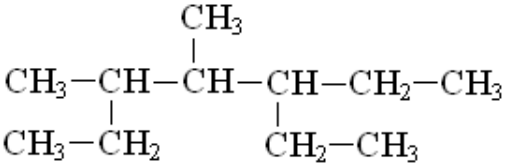
b.



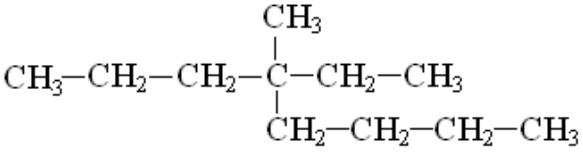
c.



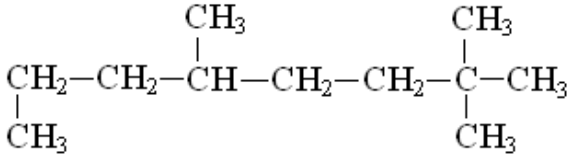
d.



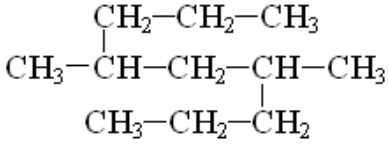
e.



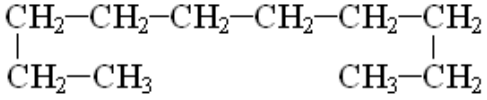
f.



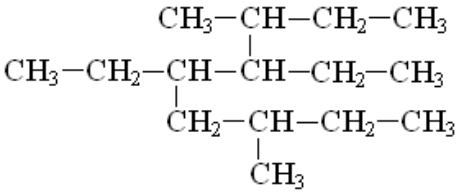
g.



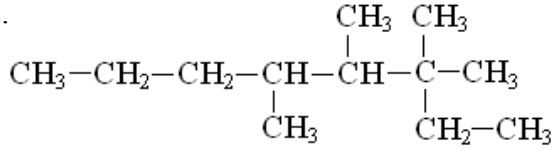
h.



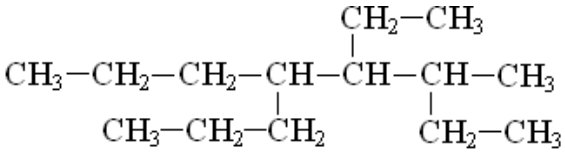
i.



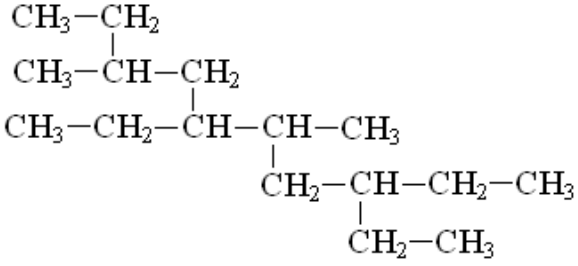
j.



k.



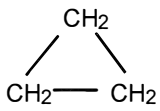
l.



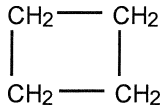
SECTION 25.6 Cyclic Alkanes

The compounds we have studied so far have been either "straight" or "branched" chains. Carbon atoms can also form rings which result in the formation of *cyclic* alkane molecules with the general formula, C_nH_{2n}. Naming the cyclic alkanes is not difficult, but the rules do differ a bit from those used to name the straight and branched chained compounds.

The name of a cyclic molecule requires the addition of the prefix "cyclo" to the name of the hydrocarbon. Note the two condensed structural formulas below.



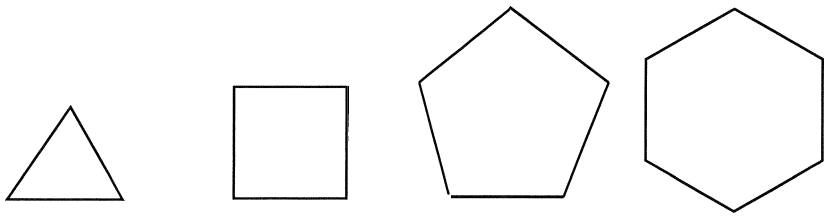
cyclopropane



cyclobutane

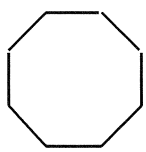
To make cyclic compounds easier to draw, a shorthand notation is used in which the hydrogens and carbons which are part of the ring are not represented at all. The rings are represented by lines, and a carbon atom is assumed to be present at each angle in the ring. The proper number of hydrogen atoms is assumed to be attached to each carbon.

For example:



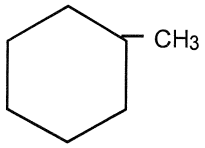
cyclopropane	cyclobutane	cyclopentane	cyclohexane
C_3H_6	C_4H_8	C_5H_{10}	C_6H_{12}

Name this compound →



{4}_____

Like the "straight-chained" compounds, cyclic molecules can also contain alkyl side chains. The same general rules for alkane nomenclature apply to the cyclics, except that all positions in a ring are equivalent, so a number is not needed to indicate the position of the alkyl group if there is only one alkyl group on the ring. For example:

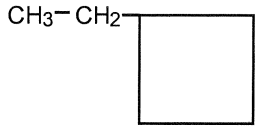


← This is called methylcyclohexane

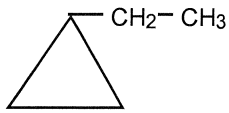
(It is NOT called 1-methylcyclohexane)

The carbon on which the alkyl group is located is automatically assumed to be number 1.

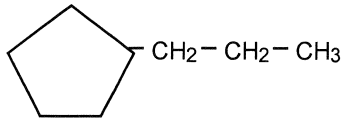
Problem 8. Name the cyclic molecules below.



a._____

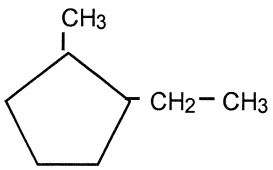


b._____

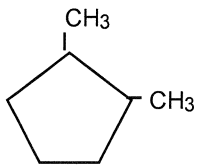


c._____

If there are two or more substituents on a ring, numbers must be used to indicate their positions. One of the substituents is always assigned position number 1, and starting at position 1, the chain is numbered either clockwise or counterclockwise so as to give the other substituents on the ring the smallest possible numbers. For example:

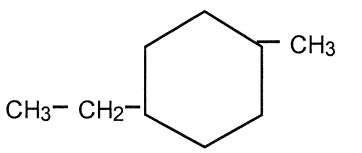


← This is called 1-ethyl-2-methylcyclopentane



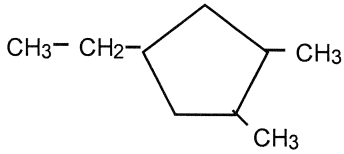
← This is called 1,2-dimethylcyclopentane

(It is NOT called 1,5-dimethylcyclopentane)



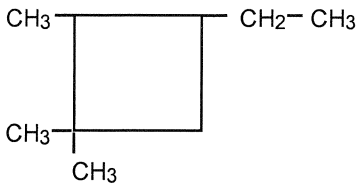
← This is called 1-ethyl-4-methylcyclohexane

(You may have wanted to call it 4-ethyl-1-methylcyclohexane, but we chose to assign the number 1 position to ethyl since it comes first, alphabetically, and since we get the same numbers,1 and 4, either way.)



← This is called 4-ethyl-1,2-dimethylcyclopentane

In the last example, we assign position 1 to the carbon in the lower right corner and number the ring counterclockwise. This gives the lowest possible set of numbers for the three substitutents on the ring.

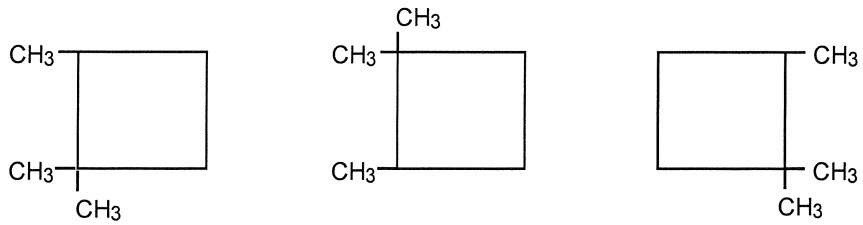


← This is called 3-ethyl-1,1,2-trimethylcyclobutane

(We numbered clockwise this time)

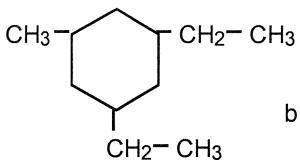
In the molecule drawn above, if we assigned position #1 to the carbon which is bonded to the ethyl group, we would have had to number counterclockwise and name the molecule: 1-ethyl-2,3,3-trimethylbutane. This was avoided because it resulted in higher numbers.

The three structures drawn below are identical. Write the name: {5}_____

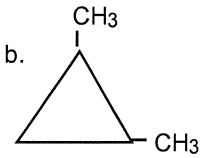


Problem 9. Name the cyclic alkanes shown below:

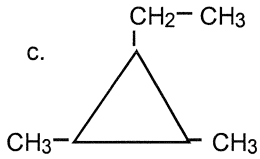
a.



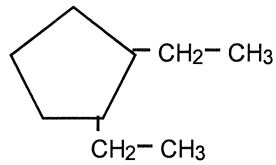
b.



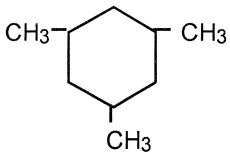
c.



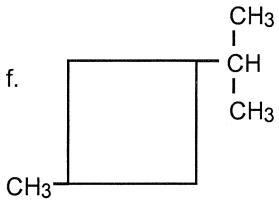
d.



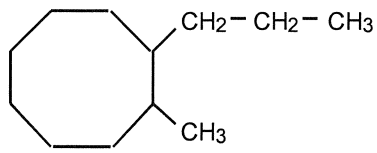
e.



f.



g.



a. _____

b. _____

c. _____

d. _____

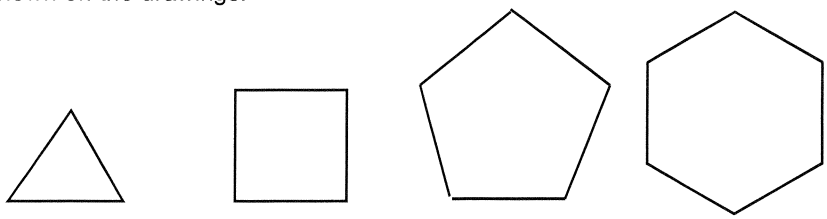
e. _____

f. _____

g. _____

ACTIVITY 25.7 Models of Cyclic Alkanes

Using a molecular model kit, construct the four cyclic molecules drawn below. The models give you some idea of what these cyclic compounds look like in three dimensions. You will also see the effects of the bond angles on the shapes of the molecules. Be sure to include all needed hydrogen atoms, even if they are not shown on the drawings.



cyclopropane	cyclobutane	cyclopentane	cyclohexane
C_3H_6	C_4H_8	C_5H_{10}	C_6H_{12}

Do any of these cyclic compounds have what you might consider to be flat rings? If so, which one(s)?

{6}_____

Here is a summary of the rules used to name alkanes:

RULE 1: Locate the longest continuous chain of carbon atoms. This will give you the name of the "parent" compound.

RULE 2: The name of the parent compound is modified by noting what alkyl groups are attached to the chain. Number the longest chain so that the alkyl group(s) will be on the lowest numbered carbons.

RULE 3: When the same alkyl group occurs more than once in a molecule, the numbers of the carbons to which they are attached are all included in the name. The number of the carbon is repeated as many times as the group appears. The number of repeating alkyl groups is indicated in the name by the use of Greek prefixes for 2, 3, 4, 5, etc. (di, tri, tetra, penta, etc.).

RULE 4: If there are two or more different kinds of alkyl groups attached to the parent chain, name them in alphabetical order.

RULE 5: The put the finishing touches on the name of an alkane, keep the following points in mind: (a) hyphens are used to separate numbers from names of substitutents; (b) numbers are separated from each other by commas; (c) the last alkyl group to be named is prefixed to the name of the parent alkane, forming one word; and (d) the suffix "-ane" indicates that the molecule is an alkane.

SECTION 25.8 Naming Alkenes

Now that you are an expert on alkanes, let's take a look at the *alkene* functional group. A functional group is a feature of a class of compounds that is responsible for its characteristic properties. The functional group of the alkanes is the single bond. The functional group of the alkenes is the *double bond*. Alkenes contain at least one double bond which exists between a pair of carbon atoms. The general formula for the straight-chained alkenes is C_nH_{2n}. The suffix to be used in the names of alkenes is "-ene." The rules for naming alkenes are the same as those for alkanes with a few additional restrictions.

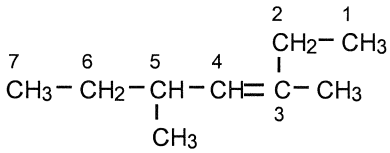
Additional Rules for the Nomenclature of Alkenes:

RULE 1: The chain chosen as the parent chain must contain the carbon–carbon double bond (C=C).

RULE 2: The parent chain must be numbered to give the carbon-carbon double bond the lowest possible number.

RULE 3: The name of the alkene must contain a number to indicate the position of the double bond.

Note the example below. The longest carbon chain alkene is numbered correctly, giving the double bond the lowest possible number.



3,5-dimethyl-3-heptene

As we number the carbons, the first carbon involved in the double bond is #3, so the parent chain is called 3-heptene. Methyl groups are located on carbons #3 and #5.

A number is not used to locate the double bond in chains which are shorter than four carbons. Two examples are below.

$CH_2 = CH_2$ ← This is called ethene, not 1-ethene

$CH_3 - CH = CH_2$ ← This is called propene, not 1-propene

Why is it that these two molecules do not require the use of the number? {7}_____

_____

Problem 10. Name the alkenes below. After you have located the longest chain containing the double bond, be sure to number the chain so that the double bond gets the lowest possible number.

a. $CH_3 - CH_2 - CH = CH_2$ _____

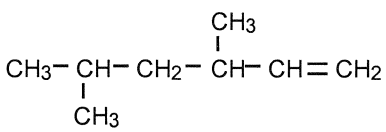
b. $CH_3 - CH = CH - CH_3$ _____

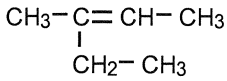
c. $CH_3 - CH_2 - CH = CH - CH_3$ _____

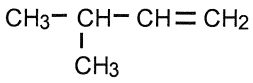
d. $CH_3 - CH_2 - CH = CH - CH_2 - CH_3$ _____

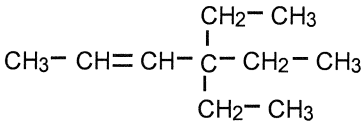
e. $CH_2 = CH_2$ _____

f. $CH_3 - CH = CH_2$ _____

g.  _____

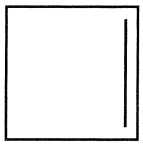
h. 

i. 

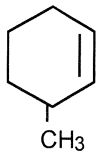
j. 

SECTION 25.9 Naming Cycloalkenes

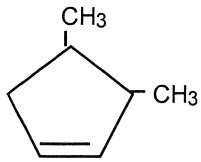
Cycloalkenes are named similarly to straight chained alkenes. The carbons in the ring that contain the double bond are always assigned the #1 and #2 positions, so numbers are used only to locate the positions of substitutents attached to the ring - not to locate the position of the double bond. The general formula for cyclic alkenes in C_nH_{2n-2}. Study the examples below.



cyclobutene

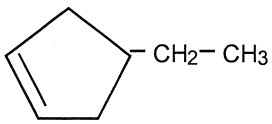


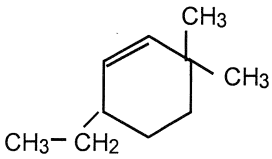
3-methylcyclohexene

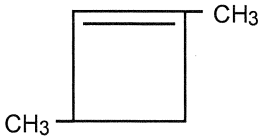


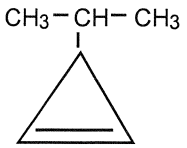
3,4-dimethylcyclopentene

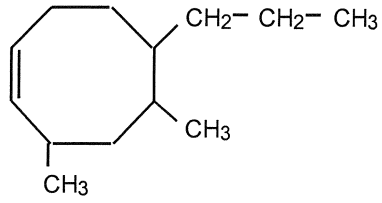
Problem 11. Name the following cycloalkenes.

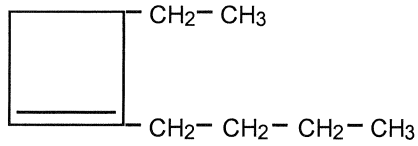
a. 

b. 

c. 

d. 

e. 

f. 

SECTION 25.10 Naming Alkynes

The functional group of the compounds known as the *alkynes* is a triple bond. The general formula for straight-chained alkynes is C_nH_{2n-2}. Alkynes are named in much the same way as the alkenes, except that their names end with the suffix "-yne", signifying the triple bond. Once again, the triple bond must be located within the parent chain, and it should be assigned the lowest possible number.

Additional Rules for the Nomenclature of Alkynes:

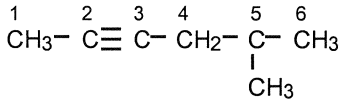
RULE 1: The chain chosen as the parent chain must contain the carbon- carbon triple bond.

RULE 2: The parent chain must be numbered to give the carbon-carbon triple bond the lowest possible number.

RULE 3: The name of the alkyne must contain a number to indicate the position of the triple bond.

As was the case with the alkenes, no number is used to locate the triple bond if the parent chain is shorter than four carbons:

$CH\equiv CH$	$CH\equiv C-CH_3$	$CH\equiv C-CH_2-CH_3$	$CH_3-C\equiv C-CH_3$
ethyne	propyne	1-butyne	2-butyne

For the example at right, the correct name is 5-methyl-2-hexyne → 

Problem 12. Name the alkynes drawn below. Be sure to number the parent chain so as to give the triple bond the lowest possible number.

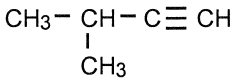
a. $CH \equiv C - CH_2 - CH_2 - CH_3$ _____

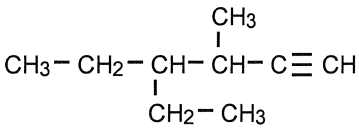
b. $CH_3 - CH_2 - CH_2 - C \equiv C - CH_3$ _____

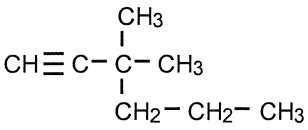
c. $CH_3 - CH_2 - C \equiv C - CH_3$ _____

d. $CH_3 - CH_2 - CH_2 - C \equiv CH$ _____

e. $CH_3 - C \equiv C - CH_2 - CH_2 - CH_2 - CH_3$ _____

f.  _____

g.  _____

h.  _____

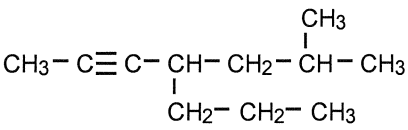
i.  _____

Table 25.1
Summary of General Formulas for Alkanes, Alkenes, and Alkynes

Class of Compound	*General Formula*
Straight-chained alkanes	C_nH_{2n+2}
Cycloalkanes	C_nH_{2n}
Alkenes	C_nH_{2n}
Cycloalkenes	C_nH_{2n-2}
Alkynes	C_nH_{2n-2}

SECTION 25.11 Review Problems

Problem 13. The names of the compounds listed below are NOT correct. Using the incorrect name, draw the structural formula in the work area. Then write the correct name of each compound on the line provided.

Incorrect Name	*Correct Name*	*Work Area*
a. 4,4-dimethylhexane	_____	
b. 2-n-propylpentane	_____	
c. 1,1-diethylbutane	_____	
d. 1,4-dimethylcyclobutane	_____	
e. 3-methyl-2-butene	_____	
f. 5-ethylcyclopentene	_____	
g. 2-n-propyl-1-propene	_____	
h. 2-isopropyl-3-heptene	_____	
i. 2,2-dimethyl-3-butyne	_____	
j. 5-octyne	_____	

Problem 14. Write condensed structural formulas for the following:

Name	*Condensed Structural Formula*
a. 4-isopropyloctane	
b. 3,4-dimethyl-4-n-propylheptane	
c. 1,1-dimethylcyclobutane	
d. 3-ethyl-3-heptene	
e. 3-ethyl-2-methyl-1-hexene	
f. 3-octene	
g. 3,3-dimethyl-1-butyne	
h. 4,4-dimethyl-2-pentyne	
i. 3-n-butyl-2-ethylcyclohexene	
j. 3,4-diethyl-4,6-dimethylnonane	

SECTION 25.12 Learning Outcomes

Before leaving this chapter, read through the learning outcomes listed below. Place a check before each outcome when you feel you have mastered it. When you have completed this task, arrange to take any quizzes or exams on this chapter, and move on to Chapter 26.

_____1. Distinguish between organic and inorganic compounds.

_____2. Distinguish between alkanes, alkenes, and alkynes.

_____3. Determine the number of carbon atoms in the longest chain of any alkane, alkene, or alkyne.

_____4. Use the IUPAC system to name alkanes, alkenes, and alkynes, given their condensed structural formulas.

_____5. Given the IUPAC names, be able to draw condensed structural formulas for alkanes, alkenes, and alkynes.