Alkanes, Isomers & Naming Branches

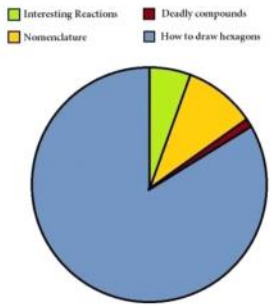
September 21, 2017 8:25 AM

Organic Chemistry Student Booklet

Chemistry 11

Organic Chemistry

Things I learned in Organic Chemistry



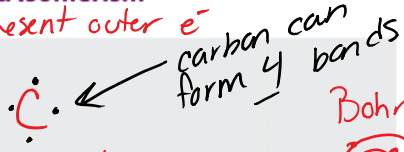
Name: Key

Block: 1, 7 + 8

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? 4

3. Classify the following compounds as ionic or covalent:

inorganic (a) Na_2CO_3 ionic

organic (b) C_2H_6 covalent

inorganic (c) CO_2 covalent

inorganic (d) CaC_2 ionic

organic (e) C_2H_5OH covalent. "alcohol"

ionic = • metal + non-metal
• e⁻ donation / accepted

covalent = • non-metal + non-metal
• sharing an e⁻ pair

Organic Compounds

Chemical compounds can be classified as belonging to one of two very large groups: organic or inorganic compounds.

Organic compounds contain carbon atoms, usually bonded to other carbon atoms and hydrogen atoms. They may also contain other elements such as halogens, nitrogen, oxygen, phosphorus, and sulphur.

$-CO_3$ metal + carbon CO_2 group 7

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 living things 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.

Figure 8.1.1 *Heating ammonium cyanate produces urea.*

ammonium cyanate inorganic salt.

urea organic compound

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 organic or *inorganic*.
- Our study of chemistry will deal mainly with inorganic compounds. (rest of year)
- Originally, organic substances were considered to be those carbon compounds that were extracted from living things, while inorganic ones were compounds that DIDNOT originate in living systems.

An organic compound is defined as a substance that contains the element carbon

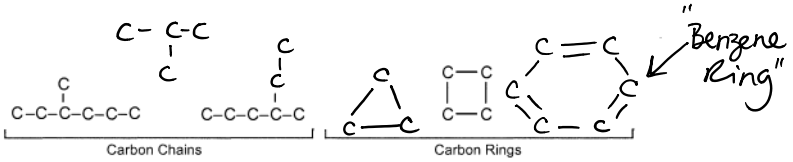
However, some compounds that contain carbon are considered to be inorganic.

A better definition may be that organic compounds have a carbon base, that carbon is the "backbone" of the compounds. chain c-c-c-..... etc.

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 synthetic (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 hydrogen) attached to the carbon atoms. Different arrangements of carbon atoms correspond to different compounds and each compound has its own characteristic properties.

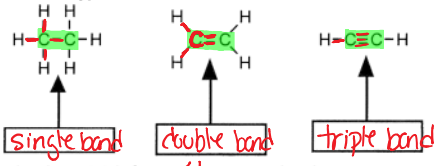
We are going to approach the subject of organic chemistry in terms of organic nomenclature. Nomenclature involves the naming of compounds

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 hydrogen
To start, we will deal exclusively with compounds composed of only carbon and hydrogen.
These are called hydrocarbons. These two elements can combine in countless ways.

hydrogen carbon

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:



single bond | double bond | triple bond.

In each case you will note that carbon has a total of 4 bonds.
This is because carbon has four valence electrons.
There are only a few carbon compounds in which carbon does not have four bonds.
One example is carbon monoxide.

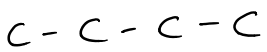
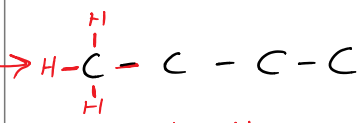
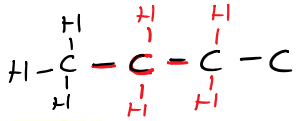
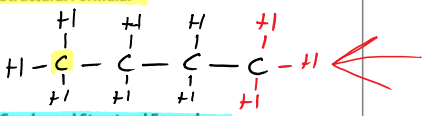
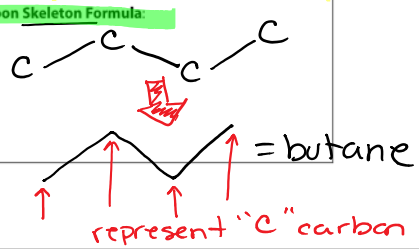
With so many different ways that carbon can bond, there are millions of known organic compounds. Every day, you use organic products such as foods, cosmetics, plastics, clothing fibres, pharmaceuticals, and fuels.

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.

molecular Formula

10 hydrogens

What to Think about	How to Do It
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.	Structural Formula: 
5. Condense this structural formula by writing the number of hydrogen atoms bonded to each carbon.	Condensed Structural Formula: $CH_3-CH_2-CH_2-CH_3$
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.	Carbon Skeleton Formula: 

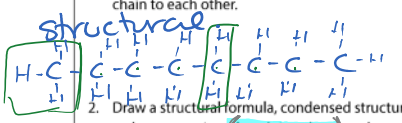
= butane

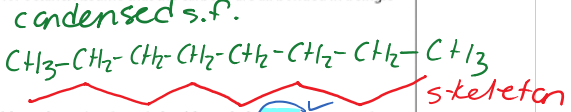
represent "C" carbon

Homework

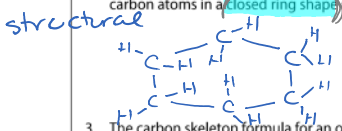
Practice Problems 1—Using Structural Formulas to Represent Organic Compounds

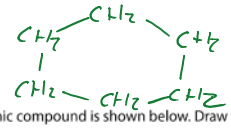
1. Octane, a constituent of gasoline, has the molecular formula C_8H_{18}. Draw a structural formula, condensed structural formula, and carbon skeletal formula for octane. Assume that the carbons are all bonded in a single chain to each other.

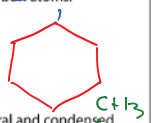




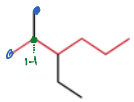
2. Draw a structural formula, condensed structural formula, and carbon skeletal formula for C_6H_{12}. Arrange the carbon atoms in a closed ring shape so that each carbon atom is bonded to two other carbon atoms.

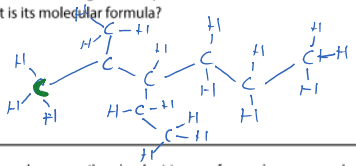


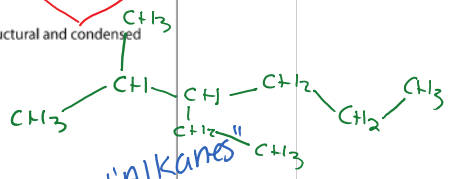




3. The carbon skeleton formula for an organic compound is shown below. Draw the structural and condensed structural formula. What is its molecular formula?







Hydrocarbons

Hydrocarbons are the simplest types of organic compounds.

Hydrocarbons are compounds that contain only carbon and hydrogen atoms.

We will examine five types of hydrocarbons:

Alkanes, cycloalkane, alkenes, alkynes, and aromatic hydrocarbons.

The Alkane family represents the simplest of the hydrocarbons.

The general formula for the compounds in this family is C_nH_{2n+2}, 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.

Alkane "-ane"

	Prefix	No. of Carbons	Name	Molecular Formula
a.	meth-	1	methane	CH_4
b.	-eth-	2	ethane	C_2H_6
c.	prop	3	propane	C_3H_8
d.	-but-	4	butane	C_4H_{10}
e.	pent	5	pentane	C_5H_{12}
f.	-hex-	6	hexane	C_6H_{14}
g.	hept-	7	heptane	C_7H_{16}
h.	oct-	8	octane	C_8H_{18}
i.	non-	9	nonane	C_9H_{20}
j.	dec-	10	decane	$C_{10}H_{22}$

C_nH_{2n+2}

The Alkanes

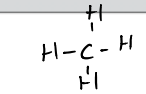
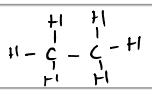
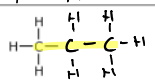
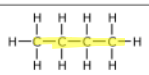
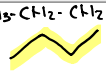
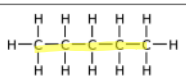
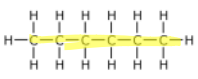
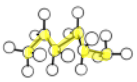
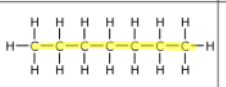
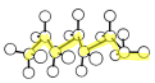
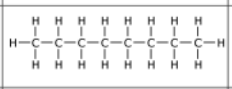
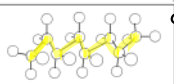
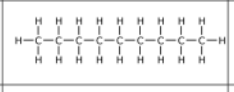
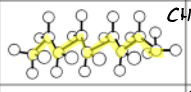
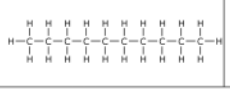
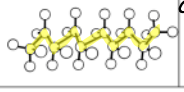
The compounds in the alkane family are often called *saturated* compounds, which means that the molecules contain only single bonds between the carbon atoms. "Saturated" also describes that there is no room for other atoms to bond to the carbon skeleton.

Naming alkanes is fairly simple. The prefix in the name of each compound indicates the number of carbon atoms present.

All alkanes have a suffix of -ane 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.

Build as part of our Lab Activity

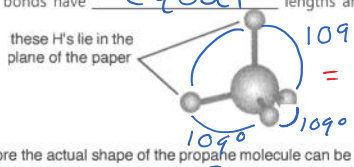
Table 8.1.2 *10 Straight-Chain Alkanes You Need to Know*

Name	Molecular formula	Structural formula	Ball and stick model	Condensed Structural Formula & Carbon Skeleton
methane	CH_4			CH_4 (no carbon skeleton)
ethane	C_2H_6			CH_3-CH_3 
propane	C_3H_8		 3D	$CH_3-CH_2-CH_3$  carbon "skeleton"
butane	C_4H_{10}			$CH_3-CH_2-CH_2-CH_3$ 
pentane	C_5H_{12}			$CH_3-CH_2CH_2-CH_2-CH_3$  * hydrogen bonds are assumed.
hexane	C_6H_{14}			$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$ 
heptane	C_7H_{16}			$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$ 
octane	C_8H_{18}			$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$ 
nonane	C_9H_{20}			$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$ 
decane	$C_{10}H_{22}$			$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$ 

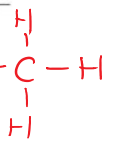
THE GEOMETRY OF ALKANES

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.

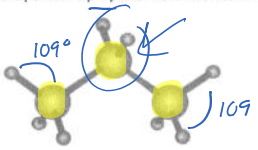
All the bonds have equal lengths and all the H-C-H angles are 109°



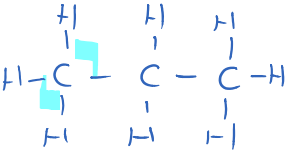
= CH_4 = methane



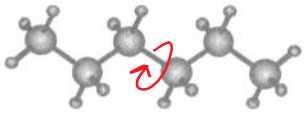
Therefore the actual shape of the propane molecule can be shown as



C_3H_8



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



6- Carbons

Each of the single bonds between the carbon atoms is able to rotate freely, leading to a highly flexible chain which can wave about and take many shapes.

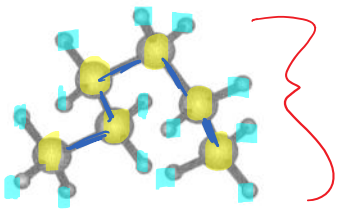
The above arrangement is one shape hexane can assume; another might be the arrangement shown below.

* all that's happened is a rotation around a single bond.

Alkanes

C_nH_{2n+2}

C_6H_{14} ✓



Is this still hexane?

Yes!

hexane → 6 carbon

→ single bonds? yes.

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

CH_4 —remove one H→

$CH_3–CH_3$ —remove one H→ $CH_3–CH_2–$

$CH_3–CH_2–CH_3$ —remove one H→ $CH_3–CH_2–CH_2–$ or $CH_3–CH–CH_3$

(remove end H) (remove middle H)

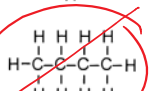
Free bonding sites

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* structural formulas. 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}		$CH_3-CH_2-CH_2-CH_3$

Practice Problem 2. Complete the exercise below.

Compound Name	*Molecular Formula*	*Condensed Structural Formula*
a. methane	CH_4	CH_4
b. ethane	C_2H_6	CH_3-CH_3
c. propane	C_3H_8	$CH_3-CH_2-CH_3$
d. butane	C_4H_{10}	$CH_3-CH_2-CH_2-CH_3$
e. pentane	C_5H_{12}	$CH_3-CH_2-CH_2-CH_2-CH_3$

Homework

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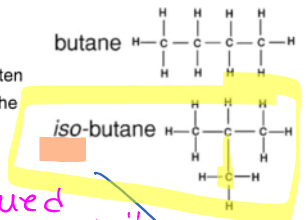
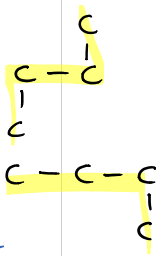
c. propane	C_3H_8	$CH_3-CH_2-CH_3$
d. butane	C_4H_{10}	$CH_3-CH_2-CH_2-CH_3$
e. pentane	C_5H_{12}	$CH_3-CH_2-CH_2-CH_2-CH_3$
f. hexane	C_6H_{14}	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$
g. heptane	C_7H_{16}	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$
h. octane	C_8H_{18}	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$
i. nonane	C_9H_{20}	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$
j. decane	$C_{10}H_{22}$	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$

p. 7

Naming Branched Alkanes

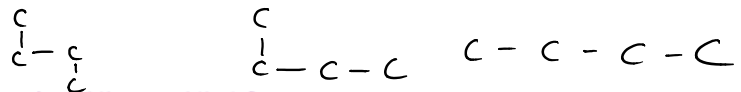




Not only do carbon atoms bond together to make chains, but often branches of carbon atoms are connected to the carbon atoms of the main chain. These branches are called substituent groups.

also called a "parent chain"

isomer
- same molecular formula
- different structure

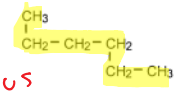


Branched Alkanes: Alkyl Groups

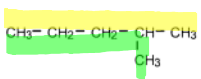
Carbon chains are not rigid structures. They can bend and flex freely. When we say that an alkane has a "straight" chain, we don't really mean straight. We mean that it is a continuous chain, rather than a *branched chain*.

The two structures below both contain **six carbon atoms**.
The one on the left is "straight," while the one on the right is branched.

straight or continuous chain



This is one continuous chain of carbon atoms.

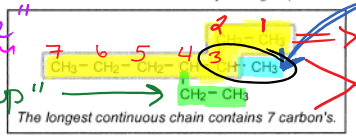


This is a branched chain of carbon atoms.

in both cases there is a $-CH_3$ branch.

Most alkanes exist as **"branched" molecules** such as the one shown below.
The longest continuous chain of carbon atoms in the molecule below is 7 (enclosed by box).
Therefore, the parent compound here is heptane => parent chain
(Remember, the longest continuous chain is not necessarily straight!)

"3-methyl-4-ethyl heptane"



"ethyl group"

"methyl group" => parent chain

2 Alkyl groups

Having identified the parent compound, we must next identify the *side chains*, commonly called Alkyl *groups*. Alkyl groups are attached 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 hydrogen 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 "yl"

remove a "H"

methane => methyl

Practice Problem 3.
Complete the exercise :

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

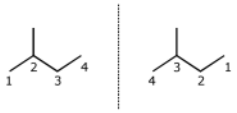
	Name of Alkyl group	#C	Condensed Structural Formula
a.	methyl	1	$-CH_3$
b.	ethyl	2	$-CH_2-CH_3$
c.	propyl	3	$-CH_2-CH_2-CH_3$
d.	butyl	4	$-CH_2-CH_2-CH_2-CH_3$
e.	pentyl	5	$-CH_2-CH_2-CH_2-CH_2-CH_3$
f.	hexyl	6	$-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$

$-CH_2$ remove 1 Hydrogen

Rules for Naming Branched Alkanes:

1. Find the longest continuous chain 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. Number carbon atoms in the parent chain starting at the end closest 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 branch → alkyl group with a prefix according to the number of carbon atoms it contains. Branch names end in "yl" instead of "ane."
   For example, a branch containing one carbon atom is called a meth *yl branch. If the branch contains two carbon atoms, it is called an* eth *yl branch.*
   List the branches in alphabetical 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.



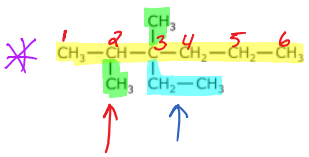
2-methyl butane **3-methyl butane**

* Naming Alkanes p. 18 #1 + 2.

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	How to Do It
1. The longest chain of carbon atoms is six and the prefix for six is "hex." Name the parent chain.	C_6 = hexane ✓
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.	2-methyl 3-methyl 2,3-dimethyl (2 of the same type of branch)
3. There is an ethyl group attached to the third carbon in the parent chain.	3-ethyl ✓
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.	

"3-ethyl-2,3-dimethyl hexane"

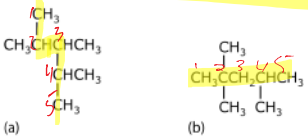
HW (Sept 26)

Practice Problems - Naming Simple Alkanes

Name the following alkanes:

1. (a) 2,3,4-trimethylpentane

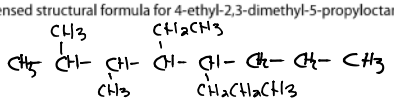
   (b) 2,2,4-trimethylpentane



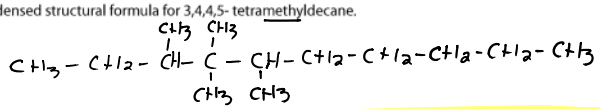
(a)

(b)

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



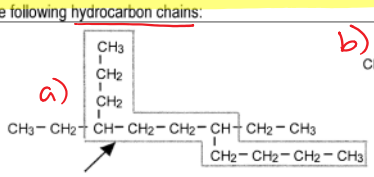
3. Draw the condensed structural formula for 3,4,4,5- tetramethyldecane.



Name the following hydrocarbon chains:

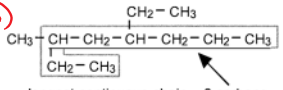
4.

a)



longest continuous chain = 11 carbons

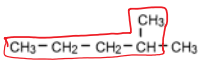
b)

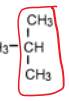


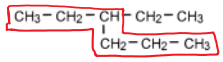
longest continuous chain = 8 carbons

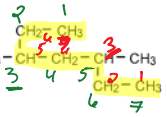
RULE 1: Locate the longest continuous chain of carbon atoms. This will give you the name of the "parent" compound

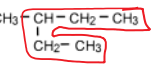
Problem 4. Draw a box around the longest continuous chain of carbon atoms in the structures below, and name the parent compound for each one.

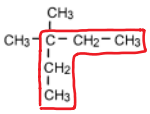
a. 

b. 

c. 

d. 

e. 

f. 

a. parent: pentane

b. parent: propane

c. parent: hexane

d. parent: heptane

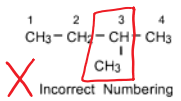
e. parent: pentane

f. parent: pentane

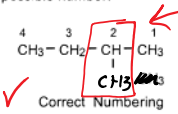
RULE 2: The name of the parent compound is modified by noting what alkyl groups are attached to the chain. Number the longest chain so that the alkyl group(s) will be on the lowest numbered carbons.

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:

eg.



X Incorrect Numbering



✓ Correct Numbering

branches with lowest numbers

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. $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-CH_2-CH_3$ — methyl

Name: 2-methyl pentane

b. $CH_3-CH_2-CH_2-\underset{\displaystyle CH_2-CH_3}{\underset{|}{CH}}-CH_2-CH_3$ — ethyl

Name: 3-ethylhexane

c. $CH_3-CH_2-CH_2-CH_2-\underset{\displaystyle CH_2-CH_2-CH_3}{\underset{|}{CH}}-CH_2-CH_2-CH_3$ — propyl

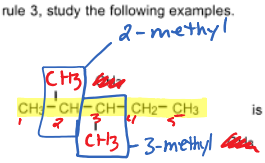
Name: 4-propyl octane

d. $CH_3-CH_2-CH_2-\underset{\displaystyle CH-CH_3}{\underset{|}{CH}}-CH_2-CH_2-CH_2-CH_2-CH_3$ — propyl

Name: 4-propyl nonane

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.

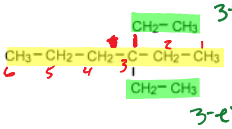


is called 2,3-dimethylpentane

2-methyl, 3-methyl } "dimethyl" 2 groups

2,3-dimethyl

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.

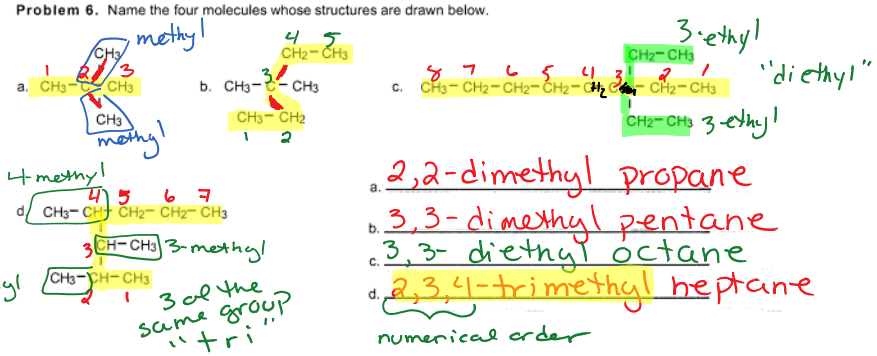


is called 3,3-diethylhexane

both attached to C3

diethyl => 2 ethyl groups

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



a. 2,2-dimethyl propane

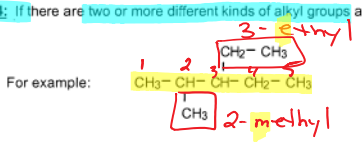
b. 3,3-dimethyl pentane

c. 3,3-diethyl octane

d. 2,3,4-trimethyl heptane

numerical order

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

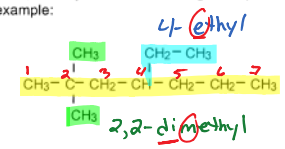


For example:

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:

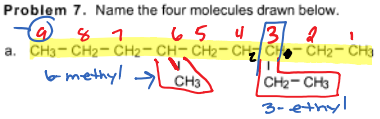


is called 4-ethyl-2,2-dimethylheptane ✓

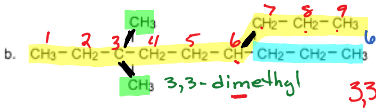
It is NOT called 2,2-dimethyl-4-ethylheptane ✗

Problem 7. Name the four molecules drawn below.

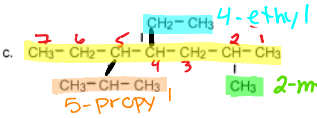
nonane



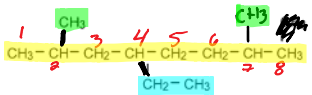
3-ethyl-6-methyl nonane



3,3-dimethyl-6-propyl nonane



4-ethyl-2-methyl-5-propyl heptane



4-ethyl-2,7-dimethyl octane

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

2

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? yes

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? yes!

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

If you named these two molecules, what would you discover?(2 same name

What is the name?(3 2,4 -dimethylpentane

Conduct Lab 23A

Full answer key posted seperately.

Homework Questions:

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? $C_nH_{(2n)+2}$

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) a) C_7 = heptane

   (b) b) C_7 = heptane

   (c) c) C_8 = octane

   (d) d) C_{10} = decane

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

   (a) 3-methylhexane

   (b) 4-ethylheptane

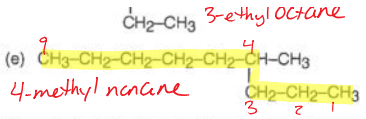
   (c) 3-ethyloctane

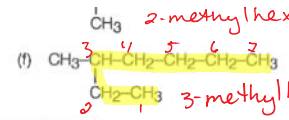
   (d) 2-methylhexane

   (e) 4-methylnonane

   (f) 3-methylheptane.

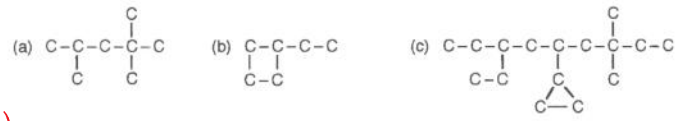
p. 14





p.14

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



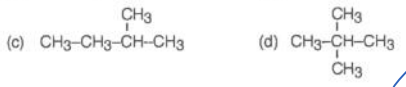
5. Draw the following hydrocarbons. Include all hydrogens.
   (a) 3-methylhexane (c) 2-methylpentane (e) 3-ethylheptane
   (b) 4-ethyloctane (d) 4-propylnonane (f) 5-propyldecane

> draw on seperate page.

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



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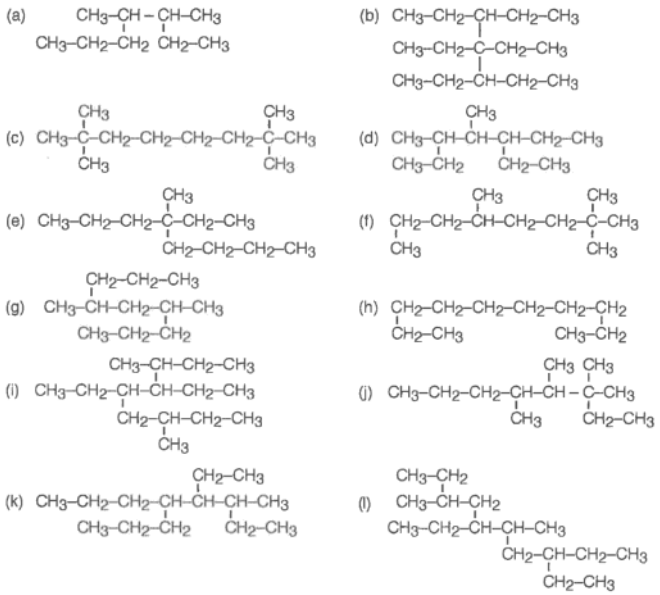
EXERCISES:

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.



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

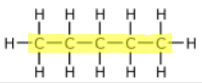
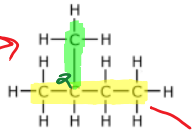
Consider Table 8.1.2 below. What do you notice about the molecular formulas of the two substances in the table?

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

$-CH_2-CH_2-CH_3$	$CH_3-\underset{\displaystyle CH_3}{\underset{\vert}{CH}}-CH_3$
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.

$CH_3-CH_2-CH_2-\underset{\displaystyle CH_2}{\underset{\vert}{CH}}-CH_2-CH_2-CH_2-CH_3$	$CH_3-\underset{\displaystyle CH_3}{\underset{\vert}{CH}}-CH_2-CH_2-CH_2-CH_2-CH_3$
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 $CH_3-\underset{\displaystyle CH_3}{\underset{\vert}{CH}}-CH_3$

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 pentane 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:

$CH_3-CH_2-CH_2-CH_2-CH_3$ (1)

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

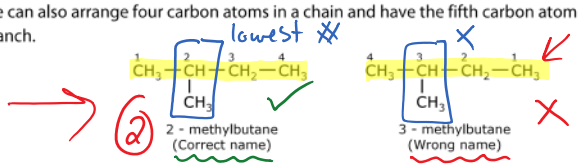
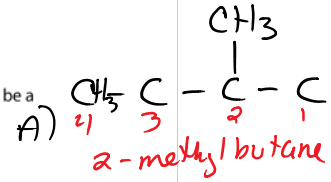


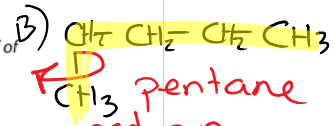
Figure 8.1.3 2-methylbutane

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.



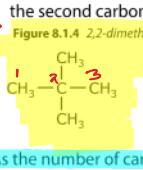
QUESTION: *Why is there not a molecule called 3-methylbutane?*

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*



mole. form. C_5H_{12}

3rd pentane isomer

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 3 structural isomers.
- C_6H_{14} has 5 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?

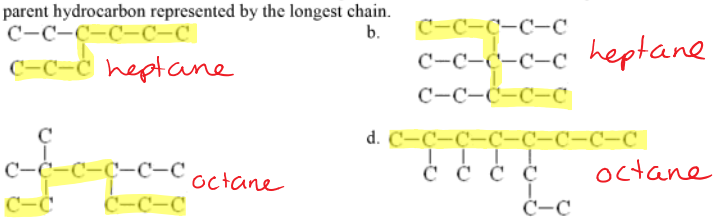
answer key posted seperately

Name:_____ Block:_____ Date:_____

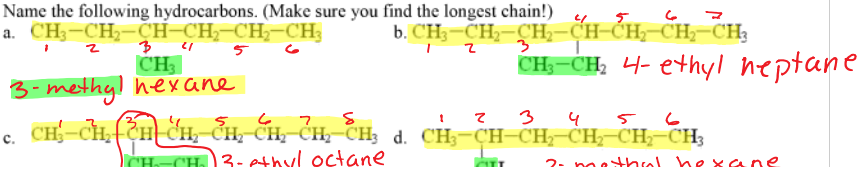
Chemistry 11 **Naming Alkanes** Assignment

Complete the following questions on a separate sheet of paper.

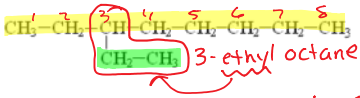
1. Determine the number of carbon atoms in the longest chain of each of the following, and name the parent hydrocarbon represented by the longest chain.

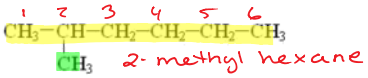


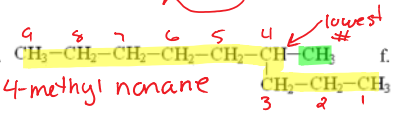
2. Name the following hydrocarbons. (Make sure you find the longest chain!)

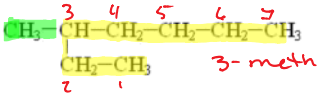


3-methyl hexane

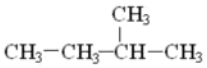
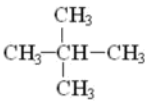
c. 

d. 

e. 

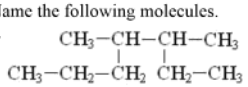
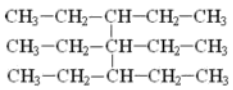
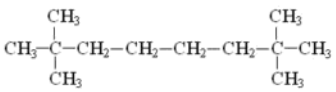
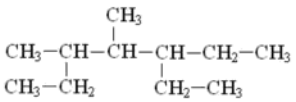
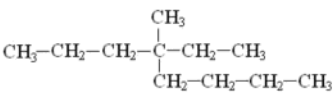
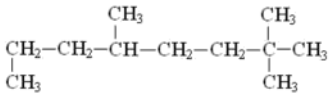
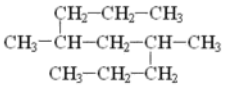
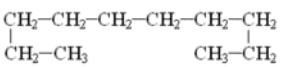
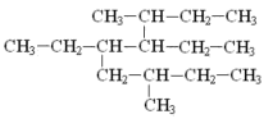
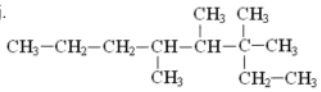
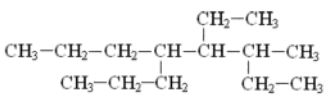
f. 

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. 

Answer KEY posted in seperate file.

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. 
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