

Name Key Block \_\_\_\_\_

Use this to check yourself and your progress.

**Hydrocarbon molecules - Petroleum - Organic Chemistry—Ball and Stick Models**

Purpose:

In this activity you will assemble models of several hydrocarbons. The goal is to relate three-dimensional shapes of molecules to the names, formulas, and pictures used to represent molecules on paper.

**Part 1 - Saturated Hydrocarbons: Modeling ALKANES**

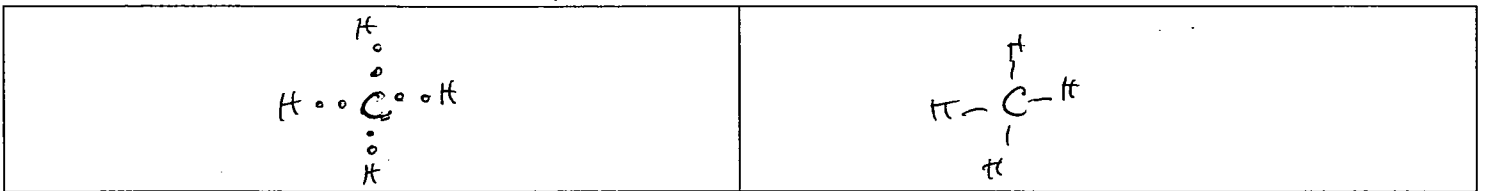
This series of hydrocarbons is called the alkanes. Saturated means that all carbon-carbon atoms are joined with a single bond. Alkanes consist of carbon atoms bonded with single covalent bonds to hydrogen atoms and/or to other carbon atoms. Alkanes are considered to be SATURATED HYDROCARBONS because each carbon is bonded to the maximum number of other atoms (four).

**PROCEDURE:**

- The molecular formula for methane is CH<sub>4</sub>. In the space below, draw the electron-dot formula AND draw the structural formula.

ELECTRON DOT FORMULA

STRUCTURAL FORMULA



- Assemble a model of methane using the balls and sticks. In the space below, as accurately as you can, DRAW the ball and stick model.

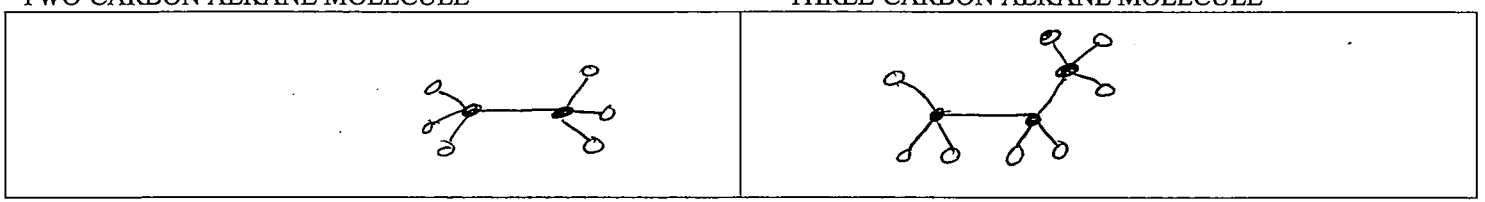


- What is the geometric molecular shape of the methane molecule? tetrahedral

- Assemble models of a two-carbon alkane molecule and a three-carbon alkane molecule. Recall that each carbon atom in an alkane is bonded to four other atoms. DRAW the ball and stick models of the two molecules in the space below.

TWO-CARBON ALKANE MOLECULE

THREE-CARBON ALKANE MOLECULE



- Draw the electron-dot AND structural formulas for the two alkane molecules shown above in a space below.

TWO-CARBON ALKANE MOLECULE

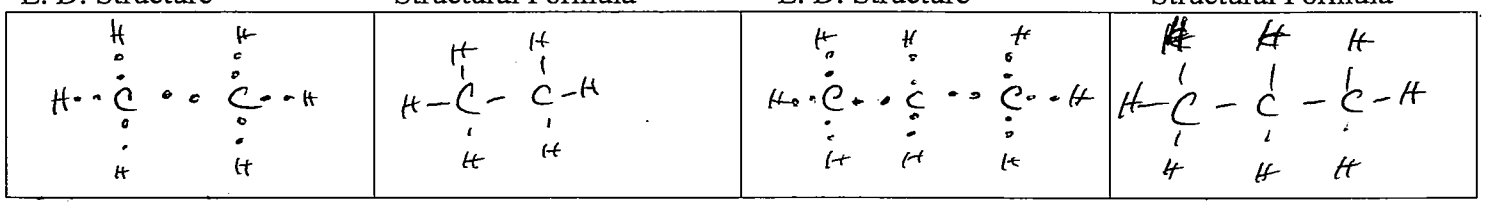
THREE-CARBON ALKANE MOLECULE

E. D. Structure

Structural Formula

E. D. Structure

Structural Formula



6. How many hydrogen atoms are present in the two-carbon alkane? 6  
 How many hydrogen atoms are present in the three-carbon alkane? 8
7. What is the molecular formula of the two-carbon alkane?  $C_2H_6$   
 What is the molecular formula of the three-carbon alkane?  $C_3H_8$
8. Carefully examine your three-carbon molecule and the structural formula that you drew for it. To how many hydrogen atoms is the middle carbon attached? 2
9. Another way to show the structure of an organic molecule is by using the CONDENSED FORMULA. This formula is a shortened version of the structural formula and can be more easily drawn. The two-carbon alkane can be shown as  $CH_3-CH_3$ . The three-carbon alkane can be shown as  $CH_3-CH_2-CH_3$ .

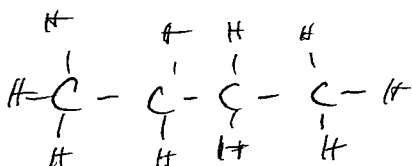
The **general molecular formula** for any alkane molecule can be written as  $C_nH_{2n+2}$  where **n is the number of carbon atoms in the molecule**. Thus, even without building any models, the formula of a four-carbon atom can be predicted: if  $n=4$ , then  $2n+2=10$ , and the formula is  $C_4H_{10}$ .

Using this general alkane formula, predict molecular formulas for the first ten alkanes. Use pg. 704. The "n" in front means "normal."

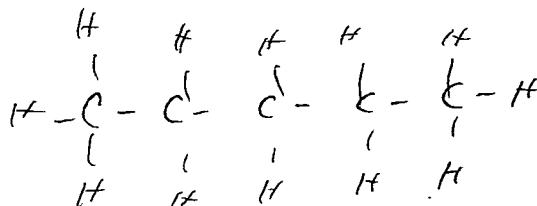
Prefix	Number of carbons	Molecular formula (not extended formula)
<u>meth-</u>	<u>1</u>	<u><math>CH_4</math></u>
<u>eth-</u>	<u>2</u>	<u><math>C_2H_6</math></u>
<u>prop-</u>	<u>3</u>	<u><math>C_3H_8</math></u>
<u>but-</u>	<u>4</u>	<u><math>C_4H_{10}</math></u>
<u>pent-</u>	<u>5</u>	<u><math>C_5H_{12}</math></u>
<u>hex-</u>	<u>6</u>	<u><math>C_6H_{14}</math></u>
<u>hept-</u>	<u>7</u>	<u><math>C_7H_{16}</math></u>
<u>oct-</u>	<u>8</u>	<u><math>C_8H_{18}</math></u>
<u>non-</u>	<u>9</u>	<u><math>C_9H_{20}</math></u>
<u>dec-</u>	<u>10</u>	<u><math>C_{10}H_{22}</math></u>

10. Write the structural formulas for butane and pentane.

BUTANE MOLECULE



PENTANE MOLECULE



11. Name the alkanes with these condensed formulas: heptane  
 A.)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$   
 Write the molecular formula  $\text{C}_7\text{H}_{16}$

B.)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$  nonane  
 Write the molecular formula  $\text{C}_9\text{H}_{20}$

12. Write a molecular formula for an alkane containing 25 carbon atoms.  $\text{C}_{25}\text{H}_{52}$

13. If the molar mass of a molecule is found by adding mass of the carbons (12 g/mol) and the hydrogens (1 g/mol), name the alkane having a molar mass of

A.) 30 g/mol ethane

B.) 58 g/mol butane

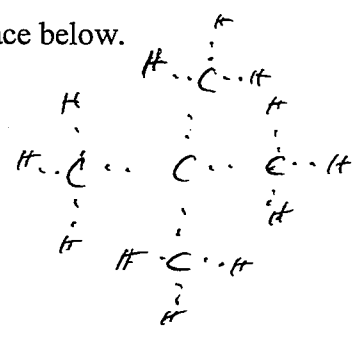
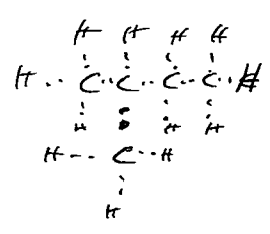
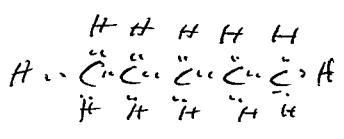
**PART 2 – Alkanes Revisited**

The alkanes considered so far are **straight-chain alkanes** in which each carbon is linked to only one or two other carbon atoms. Many other arrangements of carbon atoms in alkanes are possible. Alkanes in which one or more carbon atoms are linked to three or four other carbon atoms are called **branched-chain alkanes**.

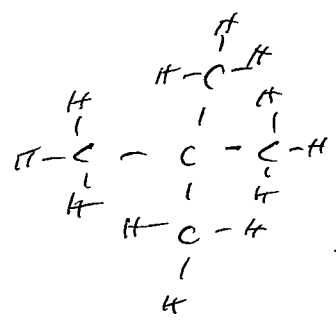
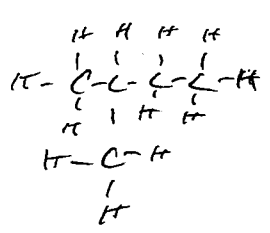
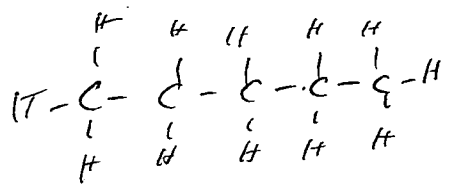
**PROCEDURE:**

Assemble ball-and-stick models of molecules with the formula  $\text{C}_5\text{H}_{12}$ , making as many arrangements of the atoms as can be constructed. All the molecules must have the molecular formula,  $\text{C}_5\text{H}_{12}$ . These molecules are called **isomers**.

A.) Draw an electron-dot formula for each isomer constructed in the space below.




B.) Draw a structural formula for each isomer in part A.



C.) How many isomers of the formula  $\text{C}_5\text{H}_{12}$  are possible? 3

D.) To distinguish the different isomers, the longest carbon chain is numbered, with the end carbon closest to the side chain receiving the lowest number. The side chains are then named as alkyl groups. Complete the following table by giving the condensed formula and the structural formula for the given alkyl groups. Pg.709

Alkyl Substituent	Condensed Formula	Structural Formula
methyl	$-\text{CH}_3$	$\begin{array}{c} \text{H} \\   \\ -\text{C}-\text{H} \\   \\ \text{H} \end{array}$
ethyl	$-\text{CH}_2\text{CH}_3$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ -\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
propyl	$-\text{CH}_2\text{CH}_2\text{CH}_3$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ -\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
isopropyl	$\text{CH}_3\overset{ }{\text{C}}\text{HCH}_3$	$\begin{array}{c} \text{H} \quad   \quad \text{H} \\   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
butyl	$-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \quad   \\ -\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
sec-butyl	$\text{CH}_3\overset{ }{\text{C}}\text{HCH}_2\text{CH}_3$	$\begin{array}{c} \text{H} \quad   \quad \text{H} \quad \text{H} \\   \quad   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
isobutyl	$-\text{CH}_2-\overset{\text{H}}{\underset{\text{CH}_3}{ }{\text{C}}}-\text{CH}_3$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ -\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \\ \text{H} \quad \text{H}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$
tert-butyl	$\begin{array}{c} \text{CH}_3 \\   \\ -\text{C}-\text{CH}_3 \\   \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{H} \\   \\ -\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
phenyl (see pg. 722)	-----	
hydroxyl (hydroxide is the root)	$-\text{OH}$	$\begin{array}{c} \text{H} \\   \\ -\ddot{\text{O}}: \end{array}$

2. A.) Draw structural formulas for as many isomers of  $C_6H_{14}$  as possible. Name each isomer.

hexane	2-methylpentane	3-methylpentane
2,2-dimethylbutane	2,3-dimethylbutane	

B.) Compare your drawings with other groups. How many isomers are possible? \_\_\_\_\_

### PART 3 - Unsaturated Hydrocarbons: Modeling Alkenes

Sometimes, in some hydrocarbons, a carbon atom bonds to three other atoms—not four. Unsaturated means that the carbon-carbon bonds can be multiple bonds instead of single bonds. This series of hydrocarbons is called the **alkenes**. If each carbon atom must possess or share eight electrons to fill its outer energy level completely, how is the carbon bonding in alkenes possible? A **double covalent bond** is a situation where 4 electrons are shared instead of 2. Compound containing double bonds are described as **unsaturated** because not all carbon atoms are bonded to their full capacity with four other atoms. Because of the double bonds, alkenes are more chemically reactive than alkanes.

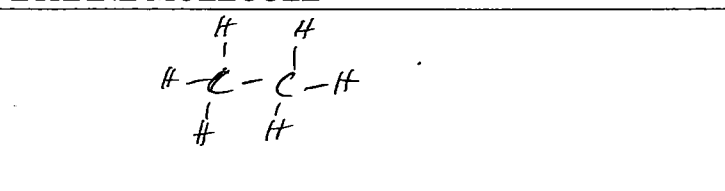
#### PROCEDURE:

1. Examine the molecular formulas of ethene,  $C_2H_4$ , and butene,  $C_4H_8$ . Recall that the general formula for alkanes was  $C_nH_{2n+2}$ . What is the general formula for alkenes is suggested by their molecular formula?

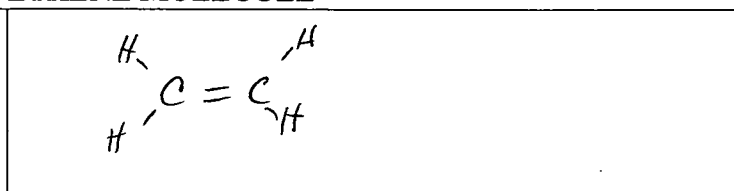
$C_nH_{2n}$

2. Assemble a model of an **ethane** molecule and one of **ethene**. Compare the arrangements of atoms in the two models. Note that although you can rotate the two carbons in ethane about the single bond, the two carbon atoms in ethene resist rotation about the double bond. This is characteristic of all double-bonded atoms whatever molecule they are found. Draw the structural formulas for ethane and ethene.

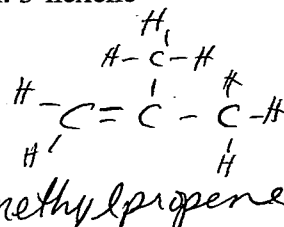
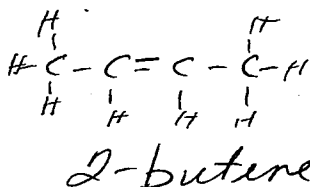
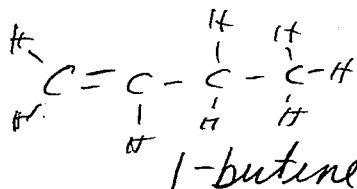
#### ETHANE MOLECULE



#### ETHENE MOLECULE

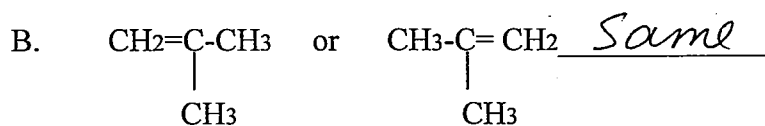
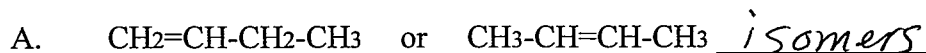


3. Build a model of butene. Compare your model of butene to those built by others in class.  
 A.) Draw the **structural formulas** for as many isomers of **butene** as possible. **Name each alkene.** This is done by identifying the number of the carbon where the double bond is formed. Ex. 3-hexene

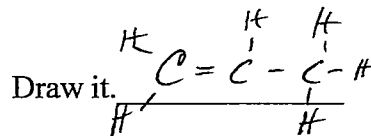


To distinguish isomers of straight-chain alkenes, the longest carbon chain is numbered, with double-bonded carbon atoms receiving the lowest numbers. The isomer name starts with the number assigned to the first double-bonded carbon atom.

4. Do each of these pairs represent **isomers**, or are they the **same** substance?



5. Construct propene. How many isomers of propene are there? one

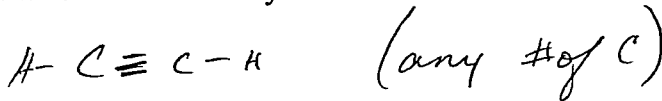


#### PART 4 – Unsaturated Hydrocarbons: Modeling Alkynes

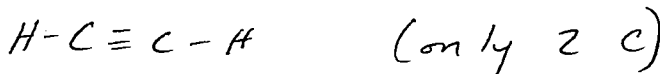
Alkynes are hydrocarbons that possess **triple covalent bonds**.

#### PROCEDURE

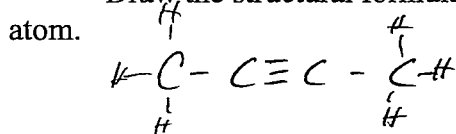
1. Based on your knowledge of molecules with single and double bonds between carbon atoms, assemble a model of any hydrocarbon that would be in the series called alkynes. Draw the structural formula for the molecule constructed in the space below.



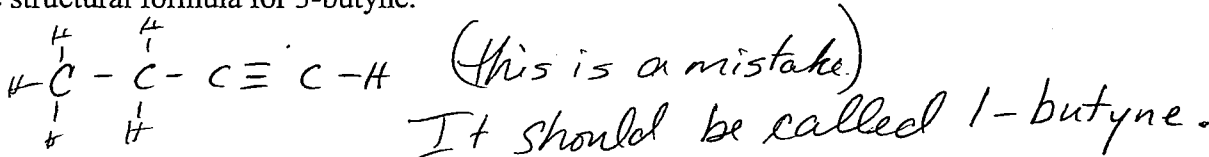
2. Draw the structural formula for ethyne, commonly called acetylene.



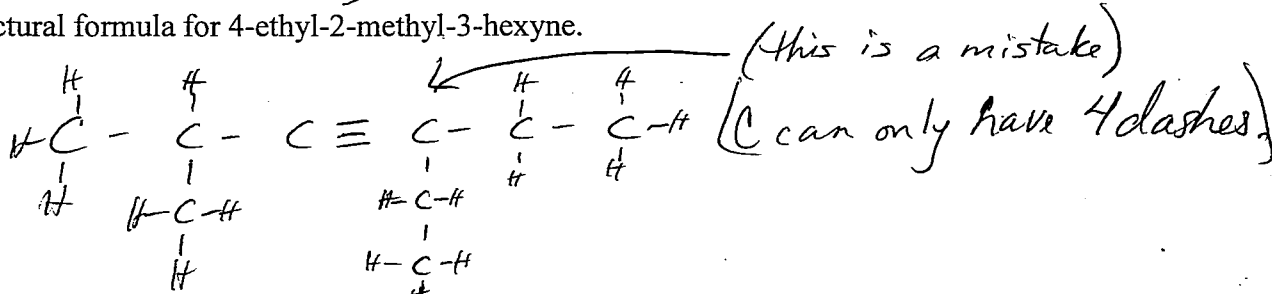
3. Draw the structural formula for 2-butyne. The 2 means that the triple bond is off of the second carbon atom.



4. Draw the structural formula for 3-butyne.



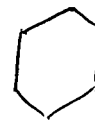
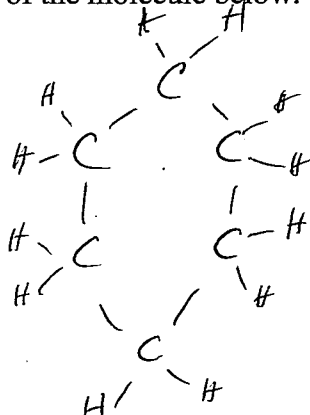
5. Draw the structural formula for 4-ethyl-2-methyl-3-hexyne.



## PART 5 – Cycloalkanes and Aromatics

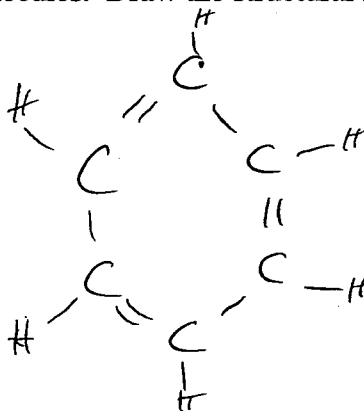
### PROCEDURE

- Construct a hexane molecule. Remove one hydrogen atom from each end carbon atom of the molecule. Carefully loop the molecule around and connect one end carbon atom of the hexane to the other end carbon atom to form a ring. Draw the structural formula of the molecule below.



- It is called cyclo hex ane.

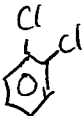
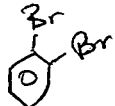
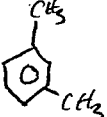
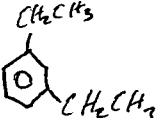


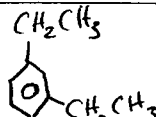
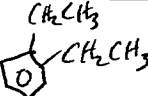
- Use the molecule constructed in #1, but remove one hydrogen atom from each carbon in the ring. Replace one single bond with a double bond. Alternate around the ring replacing every other single bond with a double bond. The result should be 3 double bonds and 3 single bonds in the ring. This final molecule is benzene, the simplest of the aromatic molecules. Draw the structural formula of the molecule below.



- Use pg. 722 to complete the following table for the common monosubstituted benzenes.

Name	Structure	Name	Structure
chlorobenzene		phenol	
toluene		nitrobenzene	
bromobenzene		styrene	

5. Draw and name the **disubstituted benzenes** listed below. If *ortho* is in the name, it means there are no carbons separating the substituents. They are on carbons 1 and 2 right next to each other. If *meta* is in the name, it means there is one carbon separating the substituents. They are on carbons 1 and 3. If *para* is in the name, it means there are two carbons separating the substituents. They are on carbons 1 and 4.

Name	Name With <i>ortho, meta, or para</i>	Structural Formula
1,2-dichlorobenzene	<i>o</i> -dichlorobenzene	
1,2-dibromobenzene	orthobromobenzene	
1,3-dimethylbenzene	<i>m</i> -methylbenzene	
1,3-diethylbenzene	<i>m</i> -diethylbenzene	
1,4-dimethylbenzene	<i>p</i> -dimethylbenzene	
1,4-diethylbenzene	<i>p</i> -ethylbenzene	
1,3-diethylbenzene	<i>m</i> -ethylbenzene	
1,2-diethylbenzene	<i>o</i> -ethylbenzene	



## PART 6 – Functional Groups and Alcohols

Most of the organic molecules in organic chemistry contain elements in addition to carbon and hydrogen. These additional atoms or groups of atoms are called functional groups. Use pg. 727 to complete the following table. You need to build and draw the structural formula for an example that is **different than the one listed in the table**. This can be done by simply adding or taking away a carbon from the examples that are listed in that table.

Class	Functional Group	Structural Formula	Name
halohydrocarbons	$R-X$	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{F} \\   \\ \text{H} \end{array}$ <p>not <math>\text{CH}_3\text{I}</math></p>	fluoromethane
alcohols	$R-OH$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{O} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$ <p>not <math>\text{CH}_3\text{OH}</math></p>	ethanol
ethers	$R-O-R'$	$\begin{array}{c} \text{H} \quad \quad \text{H} \quad \text{H} \\   \quad \quad   \quad   \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{C}-\text{H} \\   \quad \quad   \quad   \\ \text{H} \quad \quad \text{H} \quad \text{H} \end{array}$ <p>3+ C</p>	ethylmethylether
aldehydes	$\begin{array}{c} \text{O} \\    \\ \text{R}-\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \quad \text{O} \\   \quad \quad    \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$ <p>2+ C</p>	ethanal
ketones	$\begin{array}{c} \text{O} \\    \\ \text{R}-\text{C}-\text{R}' \end{array}$	$\begin{array}{c} \text{H} \quad \quad \text{O} \quad \quad \text{H} \quad \text{H} \\   \quad \quad    \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad \quad   \quad   \\ \text{H} \quad \quad \text{H} \quad \text{H} \end{array}$ <p>4+ C</p>	butan-2-one (IUPAC) butanone (common)
carboxylic acids	$\begin{array}{c} \text{O} \\    \\ \text{R}-\text{C}-\text{OH} \end{array}$	$\begin{array}{c} \text{O} \\    \\ \text{H}-\text{C}-\text{OH} \end{array}$ <p>1 or 3+ C</p>	methanoic acid
esters	$\begin{array}{c} \text{O} \\    \\ \text{R}-\text{C}-\text{O}-\text{R}' \end{array}$	$\begin{array}{c} \text{O} \quad \quad \text{H} \\    \quad \quad   \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$ <p>not 2 and 2 C</p>	methyl methanoate
amines	$R-NH_2$	$\begin{array}{c} \text{H} \quad \quad \text{H} \quad \quad \text{H} \\   \quad \quad   \quad \quad   \\ \text{H}-\text{C}-\text{C}-\text{N} \\   \quad \quad   \quad \quad   \\ \text{H} \quad \quad \text{H} \quad \quad \text{H} \end{array}$ <p>2+ C</p>	ethanamine (IUPAC) amino ethane ethylamine (common)

## How to Name Functional Groups

Functional Group	Process	Example	Structure
Halohydrocarbons	#-element (drop the end and add -o) parent	2-chloropentane	$  \begin{array}{cccccc}  & \text{H} & \text{Cl} & & \text{H} & \text{H} & \text{H} \\  &   &   & &   &   &   \\  \text{H} & - \text{C} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\  &   &   & &   &   &   \\  & \text{H} & \text{H} & & \text{H} & \text{H} & \text{H}  \end{array}  $
Alcohols	#-parent (drop the end and add -ol)	2-pentanol	$  \begin{array}{cccccc}  & \text{H} & \text{OH} & & \text{H} & \text{H} & \text{H} \\  &   &   & &   &   &   \\  \text{H} & - \text{C} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\  &   &   & &   &   &   \\  & \text{H} & \text{H} & & \text{H} & \text{H} & \text{H}  \end{array}  $
Ethers	1) Alphabetize the groups on both sides. Write <i>ether</i> at the end. 2) Name the shortest chain, but drop the end and add -oxy. Name the longest chain.	ethyl methyl ether  methoxyethane	$  \begin{array}{ccccccc}  & \text{H} & & \text{H} & & & \text{H} \\  &   & &   & & &   \\  \text{H} & - \text{C} & - & \text{C} & - & \text{O} & - & \text{C} & - \text{H} \\  &   & &   & & &   \\  & \text{H} & & \text{H} & & & \text{H}  \end{array}  $
Aldehydes	drop the end and add -al	pentanal	$  \begin{array}{cccccc}  & \text{H} & \text{H} & \text{H} & \text{H} & & \text{O} \\  &   &   &   &   & &    \\  \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\  &   &   &   &   & & & & & & \\  & \text{H} & \text{H} & \text{H} & \text{H} & & & & & &   \end{array}  $
Ketones	drop the end and add -one	propanone	$  \begin{array}{cccc}  & \text{H} & & \text{O} & & \text{H} \\  &   & &    & &   \\  \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\  &   & & & &   \\  & \text{H} & & & & \text{H}  \end{array}  $
Carboxylic Acids	drop the end and add -oic acid	methanoic acid	$  \begin{array}{c}  \text{O} \\     \\  \text{H} - \text{C} - \text{OH}  \end{array}  $
Esters	Name the substituent attached to the alcohol. Name the parent chain. Drop the end and add -oate.	ethyl propanoate	$  \begin{array}{cccccc}  & \text{H} & \text{H} & \text{O} & & \text{H} & \text{H} \\  &   &   &    & &   &   \\  \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{O} & - & \text{C} & - & \text{C} & - \text{H} \\  &   &   & & &   &   \\  & \text{H} & \text{H} & & & \text{H} & \text{H}  \end{array}  $
Amines	drop the end and add -amine	butanamine aka butan-1-amine (IUPAC)	$  \begin{array}{ccccccc}  & \text{H} & & \text{H} & & \text{H} & & \text{H} \\  &   & &   & &   & &   \\  \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{N} & - & \text{H} \\  &   & &   & &   & &   \\  & \text{H} & & \text{H} & & \text{H} & & \text{H}  \end{array}  $

## How to Draw Isomers

1. Draw the longest straight chain of carbon atoms.
2. Take one carbon off the end and put it on one of the middle carbon atoms.
3. Do not put it on the other end of the chain.
4. If more than one carbon is in the middle, put it on each until you duplicate one that's been already done.
5. Take one more carbon off the end, and put it on one of the middle carbon atoms.
6. Continue until you duplicate one that's already been done.

## How to Name Hydrocarbons

1. Number the longest chain starting with 1 closest to the first branch.
2. If there is a double bond or a triple bond, number the chain with 1 closest to the multiple bond.
3. Order the attachments (substituent alkyl groups) alphabetically. (ethyl comes before methyl)
4. Write the number in front of the alkyl group name to identify which carbon it is attached to from the parent chain.
5. If you have more than one of the same alkyl, use di-, tri-, tetra-, etc. to name the attachments. Do not alphabetize these prefixes. (triethyl still comes before methyl)
6. If you have many multiple bonds, use the prefixes to name the parent chain and to show where the multiple bonds are. (buta-1,3-diene)