

ORGANIC CHEMISTRY

Background: Organic compounds always contain **carbon** atoms which can bond to one another in chains, rings, and networks to form a variety of structures.

Organic compounds always contain _____ atoms.

Organic compounds can be named using the **IUPAC** system. **IUPAC** is an acronym for “International Union of Pure and Applied Chemists”. Even though we often associate the term “organic” with things that are natural, organic compounds can be both natural and man-made. Carbon atoms form 4 covalent bonds with other atoms, including other carbon atoms. This fact allows carbon to form an enormous variety of compounds. There are many more carbon (organic) compounds than non-carbon (inorganic) compounds. All living things on the planet Earth contain carbon compounds. Raw materials such as petroleum, natural gas, wood, and coal are products of things that were once alive. They derived their carbon from those living things.

How many covalent bonds do carbon atoms form during bonding? _____

Bonding: Carbon forms covalent bonds with other nonmetals. Remember, covalent bonding results in molecules, therefore carbon (organic) compounds are molecular. Since organic compounds are molecular they have properties of molecular substances.

Properties:

1. Most organic compounds are non-polar since they have symmetry.
2. Since organic compounds are nonpolar, they do not dissolve well in water. Instead they dissolve in oil. Remember! Like dissolves Like! There are some exceptions. Alcohols, sugars, and organic acids are organic compounds that dissolve in water.
3. Most organic compounds are not **electrolytes**. Electrolytes are substances that dissolve in water to produce a conducting solution. Why does this occur? Because the dissolving of an electrolyte will produce ions in water. Organic acids are an exception, organic acids produce ions in water and are electrolytes.
4. Organic compounds have low melting and boiling points because they are molecular and therefore have weak intermolecular forces.
5. Organic chemical reactions are usually slow compared to aqueous ionic reactions. This is because breaking and forming covalent bonds from organic compounds requires more time than the forming of ionic bonds in solution.

A carbon atom has 4 valence electrons and therefore shares 4 pairs of electrons when it bonds (4 covalent bonds). If the four bonds are single bonds they spread out to the corners of a **tetrahedron** (exs: carbon tetrachloride CCl_4 and methane CH_4). Carbon atoms are capable of forming single, double or triple covalent bonds.

A single covalent bond — has one shared pair of electrons :. A double covalent bond = has two shared pairs of electrons : :. A triple covalent bond \equiv has three shared pairs of electrons : : :.

Let's check our understanding of organic compounds so far. Hint! Look at pg. 1

1. Are most organic compounds polar or nonpolar (choose one).

Why?

2. Do most organic compounds dissolve well in oil or water (choose one).

Why?

3. List 3 organic compounds that do dissolve well in water.

4. Describe: electrolyte

5. Are most organic compounds electrolytes?

6. What kind of organic compound is an electrolyte?

7. Do most organic compounds have high or low melting and boiling points?
(choose one).

Why?

8. Are organic reactions fast or slow compared to aqueous ionic reactions?
(choose one)

Why?

9. How many shared pairs of electrons are in a single covalent bond? _____

10. How many shared pairs of electrons are in a double covalent bond? _____

11. How many shared pairs of electrons are in a triple covalent bond? _____

HYDROCARBONS

Hydrocarbons are compounds that only contain **hydrogen** and **carbon**. **Saturated** hydrocarbons contain only single carbon-carbon bonds. **Unsaturated** hydrocarbons contain at least one double or triple carbon-carbon bond. Saturated hydrocarbons are more stable than unsaturated hydrocarbons and are less likely to react or decompose. This is why humans are concerned about consuming too much saturated fat. Saturated fats are hydrocarbons that are not broken down easily by the human body.

Hydrocarbons are grouped into different categories based on the bonding between carbon atoms. A hydrocarbon category is known as a **homologous series**. Members of a homologous series have the same **general formula**. A general formula determines the # of hydrogen atoms that will be bonded to an amount of carbon atoms in a hydrocarbon.

The names of the **homologous series** we will learn about are the:

Alkanes are **saturated** hydrocarbons containing **only single** carbon-carbon bonds.

Alkenes are **unsaturated** hydrocarbons containing **one double** carbon=carbon bond.

Alkynes are **unsaturated** hydrocarbons containing **one triple** carbon \equiv carbon bond.

Describe the following terms: ☺

1. hydrocarbon _____

2. saturated hydrocarbon _____

3. unsaturated hydrocarbon _____

4. alkane _____

5. alkene _____

6. alkyne _____

7. homologous series _____

8. general formula _____

Transfer the information from Table Q into the blank table below. ☞

Table Q
Homologous Series of Hydrocarbons

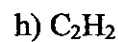
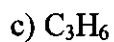
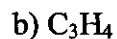
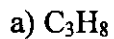
Name	General Formula	Examples	
		Name	Structural Formula

Table Q shows the general formulas for the **homologous series** of alkanes, alkenes and alkynes.

You will need to identify if a hydrocarbon is an alkane, alkene, or alkyne based on which general formula it fits. You will also have to state whether it is saturated or unsaturated.

Examples:

Identify each hydrocarbon compound as **alkane, alkene, or alkyne** and state if it is **saturated or unsaturated**. ☞



Naming Alkanes: The name of any alkane will end in “**ane**”. Use the prefix from Table P to indicate the number of carbon atoms followed by “ane”.

Use the table below to name and draw the structural formula for the first 6 alkanes. ☺

Hydrocarbon name	Molecular Formula	Structural Formula
<u>Methane</u>	CH ₄	

Notice there are only single bonds present in alkane hydrocarbons (saturated).
A series of compounds that have the same general formula is called a homologous series.
Table Q shows the general formulas for the homologous series of alkanes, alkenes and alkynes.

All **alkanes** have the same general formula C_nH_{2n+2} (n = the number of carbon atoms).

What is the general formula for any alkane? _____.

Naming Alkenes: The name of any alkene will end in “ene”. Use the prefix from Table P to indicate the number of carbon atoms followed by “ene”. The position of the double bond must be indicated when the alkene has more than 3 carbon atoms. This is done by numbering the carbon atoms from the direction (left or right) which results in the double bond following the lowest # carbon atom. Indicate the # of the carbon atom which precedes the double bond before the name of the alkene.

Use the table below to name and draw the structural formula for the first 6 alkenes.

For this exercise place the double bond after the first carbon atom. ☺

Hydrocarbon name	Molecular Formula	Structural Formula
Ethene	C_2H_4	

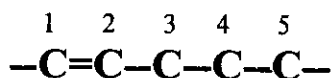
Notice there is only one double bond present in alkene hydrocarbons. A series of compounds that have the same general formula is called a homologous series. Table Q shows the general formulas for the homologous series of alkanes, alkenes and alkynes.

All alkenes have the same general formula C_nH_{2n} (n = the number of carbon atoms).

What is the general formula for any alkene? _____

Locating and Identifying Special Features on Organic Compounds.

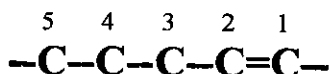
When a special feature is part of an organic compound it needs its location identified. Its location is designated using a numbered carbon atom. Carbon atoms are numbered, starting at the end closest to the special feature.



This 5 carbon molecule has a double bond between the 1st and 2nd carbon atom.

It is described as 1-pentene.

When the same molecule is turned around it is still the same molecule. Therefore; it still has the same name.



It is described as 1-pentene.



Both of the above molecules are the same and named 2-hexene. The double bond is between the 2nd and 3rd carbon atoms.

Think of the double bond as following the # 2 carbon atom.

Naming Alkynes: The name of any alkyne will end in “yne”. Use the prefix from Table P to indicate the number of carbon atoms followed by “yne”. The position of the double bond must be indicated when the alkyne has more than 3 carbon atoms. This is done by numbering the carbon atoms from the direction (left or right) which results in the triple bond following the lowest # carbon atom. Indicate the # of the carbon atom which precedes the triple bond before naming the alkyne.

Use the table below to name and draw the structural formula for the first 6 alkynes.

For this exercise place the triple bond after the first carbon atom. ☺

Hydrocarbon name	Molecular Formula	Structural Formula
Ethyne	C_2H_2	

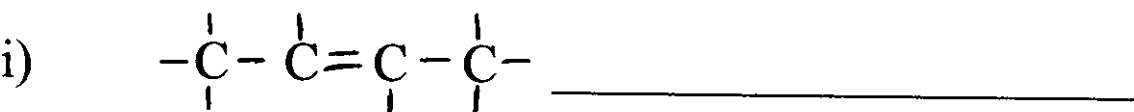
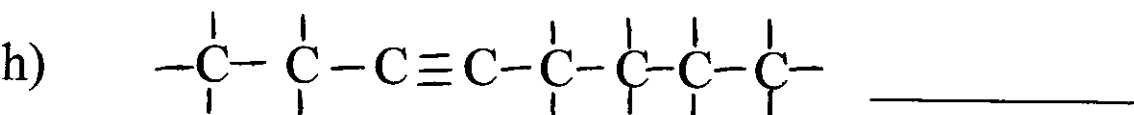
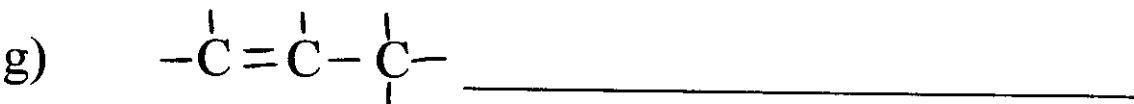
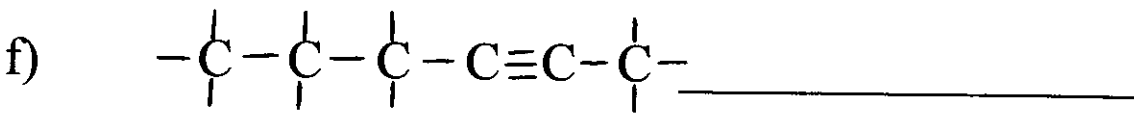
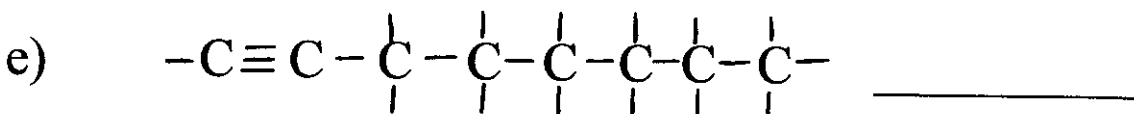
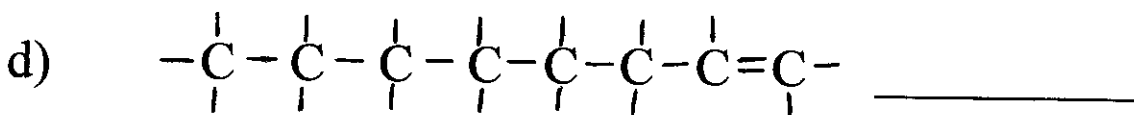
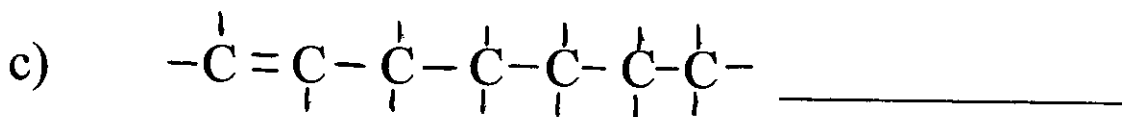
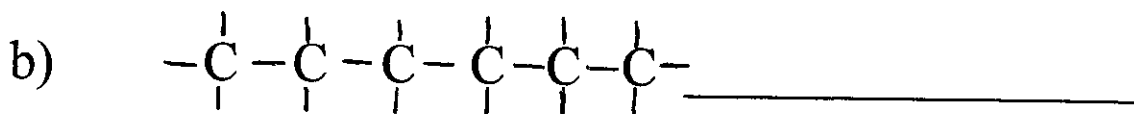
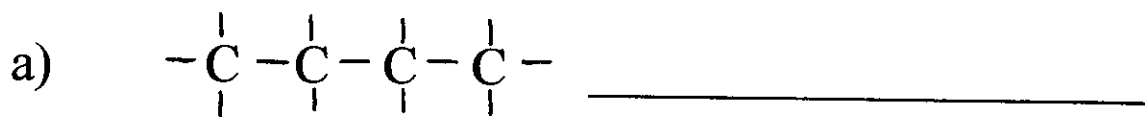
Notice there is only one triple bond present in alkyne hydrocarbons.

A series of compounds that have the same general formula is called a homologous series. Table Q shows the general formulas for the homologous series of alkanes, alkenes and alkynes.

All alkynes have the same general formula C_nH_{2n-2} (n = the number of carbon atoms).

What is the general formula for any alkyne? _____

Name the following straight chained hydrocarbons. Refer back to pages 3 – 7.



Oldie but Goodie: an older naming system indicates straight chain by using “n” to indicate normal straight chain.

Exs: n-hexane, n-octane, & n-butane



How to represent organic compounds.

Organic compounds can be represented by the use of a **name**, a **molecular formula**, a **structural formula**, a **condensed structural formula**, or a **skeleton structure**.

Example: Name: *Hexane*

Molecular formula (from the general formula)

Structural formula (shows every atom and bond)

Condensed structural formula lists each carbon with whatever it is bonded to.

Skeleton structure (only shows the carbon atoms and the bonds). A skeleton structure assumes that there is a **hydrogen** atom on the end of every bare bond.



For each of the following hydrocarbons draw the molecular formula, condensed structural formula, and skeleton structure. Hint! Look at pg. 11

Molecular formula	Condensed structural formula	Skeleton Structure
a) propane		
b) octane		
c) ethene		
d) 3-hexene		
e) ethyne		
f) 2-pentyne		

Hydrocarbon Size and Intermolecular Forces

Generally speaking, the larger (more massive) a hydrocarbon is, the greater its intermolecular forces. **Remember**, intermolecular forces are responsible for properties such as **melting point** and **boiling point** as well as **phase** (solid, liquid, or gas) at a given temperature.

Large molecules have **strong** intermolecular forces, resulting in **high** melting



and boiling points.

Small molecules have **weak** intermolecular forces resulting in **low** melting and boiling points.

Fill in the following blanks with high, low, weak, or strong

Small molecules have _____ intermolecular forces resulting in _____ melting and boiling points.

Large molecules have _____ intermolecular forces resulting in _____ melting and boiling points.

Intermolecular forces are responsible for melting and boiling point, vapor pressure and phase at a given temperature.

The following table illustrates this concept.

Name of Alkane	Molecular Formula	Mass (g)	Melting Point °C	Boiling Point °C	Phase at room temp. 25 °C
propane	C ₃ H ₈	44	-187°C	-42°C	gas
butane	C ₄ H ₁₀	58	-138°C	0°C	gas
pentane	C ₅ H ₁₂	70	-130°C	36°C	liquid
hexane	C ₆ H ₁₄	86	-95°C	69°C	liquid
heptane	C ₇ H ₁₆	100	-90°C	99°C	liquid
octane	C ₈ H ₁₈	114	-57°C	126°C	liquid
nonane	C ₉ H ₂₀	128	-53°C	151°C	liquid
eicosane	C ₂₀ H ₄₂	282	37°C	344°C	solid

Which compound is expected to have a higher melting point, octane or pentane? **Why?**

Alkyl groups: Alkyl groups are alkanes with an end hydrogen atom removed. Their names are based on the alkane from which they were derived. To name alkyl groups, use the prefix that indicates the # of carbon atoms and end the name with “yl”. An alkyl group can attach to a straight chain hydrocarbon and convert it to a branched chain hydrocarbon.

Examples: If you remove one hydrogen atom from methane it becomes “methyl”. If you remove one hydrogen atom from ethane it becomes “ethyl”, and so on.

Use the table below to name the first 3 alkyl groups and draw their structural formula. ☺

Name	Structural Formula

Branched chain hydrocarbons. Branched chain hydrocarbons are hydrocarbons that contain one or more branch. These branches are alkyl groups.

Naming branched chain hydrocarbons: In order to name branched chain hydrocarbons we must determine the **longest chain** of carbon atoms. This chain may make one or more turns. This “longest chain” is known as the **parent chain**. The carbons of the parent chain are numbered so the first named alkyl group will have the lowest possible #. If the same alkyl group appears 2 times the prefix “**di**” will be used. If the alkyl group appears 3 times the prefix “**tri**” will be used. If the alkyl group appears 4 times the prefix “**tetra**” will be used. If 2 different alkyl groups are present, list them in alphabetical order along with their carbon # location.

What is meant by parent chain? _____

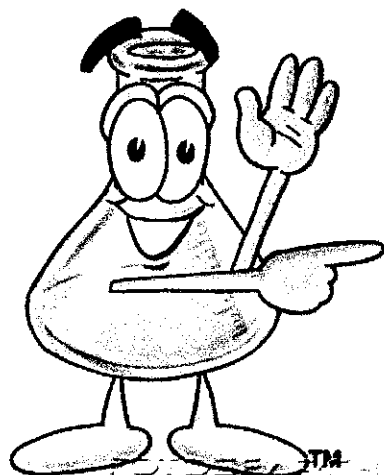
Use a number to indicate the value of each prefix: **di** _____, **tri** _____, **tetra** _____

How to name branched chain hydrocarbons:

Step 1: State the number or numbers of the carbon atoms that the alkyl groups are attached to. Every alkyl group needs its location “#” stated.

Step 2: State the name of the alkyl group or groups (alphabetical order).

Step 3: State the name of the parent hydrocarbon (longest continuous chain).



More challenge problems.

a) Draw the skeleton structure of 3-ethyl-4,4-dimethyldecane

b) Draw the skeleton structure of 4-butyl-2,2-dimethyloctane