Organic Chemistry

Word	Definition
Addition reaction	Halogen atoms break the double or triple bond on an unsaturated hydrocarbon chain and bond to either side of where the bond was broken.
Alcohol	A hydrocarbon with an –OH (hydroxyl) group somewhere on the chain.
Aldehyde	A hydrocarbon with a –CO (carbonyl) group bonded onto a primary carbon.
Alkane	A hydrocarbon with the general formula C_nH_{2n+2}, where all of the carbon-to-carbon bonds are single bonds.
Alkene	A hydrocarbon with the general formula C_nH_{2n}, where one of the carbon-to-carbon bonds is a double bond.
Alkyl group	An alkane fragment substituted onto a hydrocarbon chain, example *methyl*.
Alkyne	A hydrocarbon with the general formula C_nH_{2n-2}, where one of the carbon-to-carbon bonds is a triple bond.
Allotrope	A molecular form of an element. Oxygen has two allotropes: O_2 (diatomic oxygen) and O_3 (ozone).
Amide	A hydrocarbon with a –CO-NH- (amide) group somewhere on the chain.
Amine	A hydrocarbon with a –N= (amine) group somewhere on the chain.
Combustion	Organic molecule reacts in the presence of oxygen to form carbon dioxide and water vapor. This is a highly exothermic reaction also known as “burning”.
Dehydration synthesis	The joining of two organic molecules by the removal of water by a catalyst (dehydrating agent, often concentrated sulfuric acid).
Ester	A hydrocarbon with a –COO (carboxyl) group bonded onto a secondary carbon.
Esterification	The dehydration synthesis of an ester by reacting an organic acid with a primary alcohol.
Ether	A molecule consisting of two alkyl groups on either side of an oxygen atom.
Etherification	The dehydration synthesis of an ether by reacting two molecules of primary alcohol.
Fermentation	The anaerobic digestion of simple sugars by yeast to produce ethanol and carbon dioxide.
Halocarbon	A hydrocarbon that has had one or more halogen atoms substituted or added to the carbon chain.
Hydrocarbon	An organic molecule composed of hydrogen and carbon.
Isomer	Molecules with the same molecular formula, but with different structural formulas
Ketone	A hydrocarbon with a –CO (carbonyl) group bonded onto a secondary carbon.
Monomer	A single molecule, usually an alkene or alkadiene (addition polymerization) or a diol and dicarboxylic acid (dehydration polymerization).
Organic acid	A hydrocarbon with a –COOH (carboxyl) group bonded onto a primary carbon.
Polymer	A huge chain of connected monomers. Examples include DNA, rayon, silk, polybutadiene and polyisoprene (rubber), polypropylene, polyvinyl chloride, polytetrafluoroethene, polystyrene (plastic)
Polymerization	The joining of monomer units by addition reactions or dehydration synthesis to form enormous macromolecules called polymers.
Primary	Positional description of a carbon on the end of a hydrocarbon chain that is only directly bonded to one other carbon atom.
Saponification	The hydrolysis of a glycerol ester (fat) by a strong base to form glycerol and soap.
Saturated Hydrocarbon	A hydrocarbon with all single carbon-carbon bonds.
Secondary	Positional description of a carbon in the middle of a hydrocarbon chain that is directly bonded to two other carbon atoms.
Substitution reaction	Halogen atoms replace hydrogen atoms on a saturated hydrocarbon chain.
Tertiary	Positional description of a carbon in the middle of a hydrocarbon chain that is directly bonded to three other carbon atoms
Unsaturated Hydrocarbon	A hydrocarbon with one or more double or triple carbon-carbon bond.

Topic 1) Introduction To Organic Chemistry (HW: p. 23-25)

Essential Question: What are we made of that makes us possible to be alive?

Primordial soup. Doesn't sound all that appetizing, does it? You won't find it on the menu of most restaurants, but it was the broth from whence we all came. The chemistry of life has been shown to permeate the universe, small strands of molecules containing carbon with the potential of coming together in just the right way to get it started. There is a theory that comets not only brought water to our planet, but the seeds of life itself. However it got started, life has had a hold on the planet for a couple of billion years, mostly in the form of viruses and then bacterium. Then, less than a billion years ago, multi-celled organisms exploded on the scene, and ever more complex organisms evolved. From the tiniest little mad-cow-disease causing prion to the most complex organism on the planet (the cat, of course…did you think I was talking about humans?), the one element that has made it all possible is carbon.

Yes, carbon, that humble element that we dig out of the ground as coal, that is the primary element of crude oil (petroleum) and that is sought after on wedding bands across the world, is responsible for the complex nature of life. In this unit, you will get a whiff of that aromatic subject we call…ORGANIC CHEMISTRY. In college, there is a whole course devoted to basic organic chem., sometimes affectionately (or not so affectionately) called "O Chem." Two whole semesters, including labs, followed by biochemistry, are part of the program for those who choose the biological or medical professions. We will skim the very surface of this complex subject, and do so with five topics.

ORGANIC CHEMISTRY - the chemistry of carbon and its compounds.

PROPERTIES OF CARBON COMPOUNDS

1) Carbon forms 4 covalent bonds which may be single, double or triple. This is due to the four unpaired valence electrons that carbon has in its ground state. **These four bonds have a TETRAHEDRAL arrangement.**

2) Most organic compounds are nonpolar or weakly polar. This means that most are held together by London dispersion forces, and result in the following properties:

a) low melting and boiling point
b) high vapor pressure (volatile)

3) There are currently only 60 000 inorganic compounds known to exist, but **there are millions of organic compounds known**, and that number grows daily. Many of these compounds are found as part of biological processes, hence the name **organic**. As we develop new medicines, new fuel formulations, discover new organisms, the number of known organic molecules continues to grow.

4) Being largely nonpolar, **most organic compounds are insoluble and immiscible (unmixable) in water.** If you find a solid that is soft, has a low melting point and does not dissolve in water, then it is very likely an organic solid.

5) They undergo combustion, or reaction with oxygen to produce CO_2 + H_2O. This is the basis for much of our energy production in the United States. Electricity is generate by burning coal, oil or natural gas, using the heat to turn water to steam, which turns turbine blades, which turns a generator. Automobiles, motorcycles, ATV's, snowmobiles, lawnmowers, chainsaws and leaf blowers all are powered off of burning gasoline (octane):

$$2\ C_8H_{18}\ (l) + 25\ O_2\ (g) \longrightarrow 16\ CO_2\ (g) + 12\ H_2O\ (g)$$

6) They decompose upon heating in absence of oxygen to form their component elements. This is how crude oil formed. Organisms in the sea collected on the sea floor as they died over millions of years, were covered by sediment and decomposed into a thick goo called crude oil.

7) Organic reactions, being complex, are much slower than inorganic reactions. Organic compounds are formed by covalently bonding nonmetals. It takes a lot more energy to break a covalent bond than an ionic bond, so to keep the reactants from burning by adding heat, catalysts are often uses. Even so, organic reactions are much slower than inorganic reactions, and more prone to errors in the laboratory.

HYDROCARBONS

Oil. Black gold, Texas Tea. Oozing slowly out of a fissure in the ground, this thick, gooey black liquid was known to the ancients. It was used to light lamps, set on fire and thrown out at invading armies laying siege to cities. Eventually, people began to realize that oil was not a pure substance, but was a mixture of organic molecules called hydrocarbons. Hydrocarbons are molecules made only of carbon and hydrogen atoms. From simple molecules like methane (natural gas, CH_4) to propane (cylinder gas, C_3H_8) to butane (lighter fluid, C_4H_{10}) to octane (gasoline, C_8H_{18}) and thousands of other molecules, hydrocarbons have been the backbone to our energy industry. They come out of the ground all mixed together, and this crude oil (petroleum) is shipped to oil refineries, where the mixture is heated and separated on the basis of boiling point. This is called **fractional distillation**. Light hydrocarbons with low boiling points separate from those with higher boiling points in a distillation tower, where the distillate is collected and sent out to be used as gasoline, propane, butane, home heating oil, kerosene, airplane fuel, diesel, asphalt and other hydrocarbons that are used to manufacture lubricants (motor oil, WD40 and mineral oil, for example), oil-based paints and stains, medications, plastics, rubber and other materials that have become vital to our way of life.

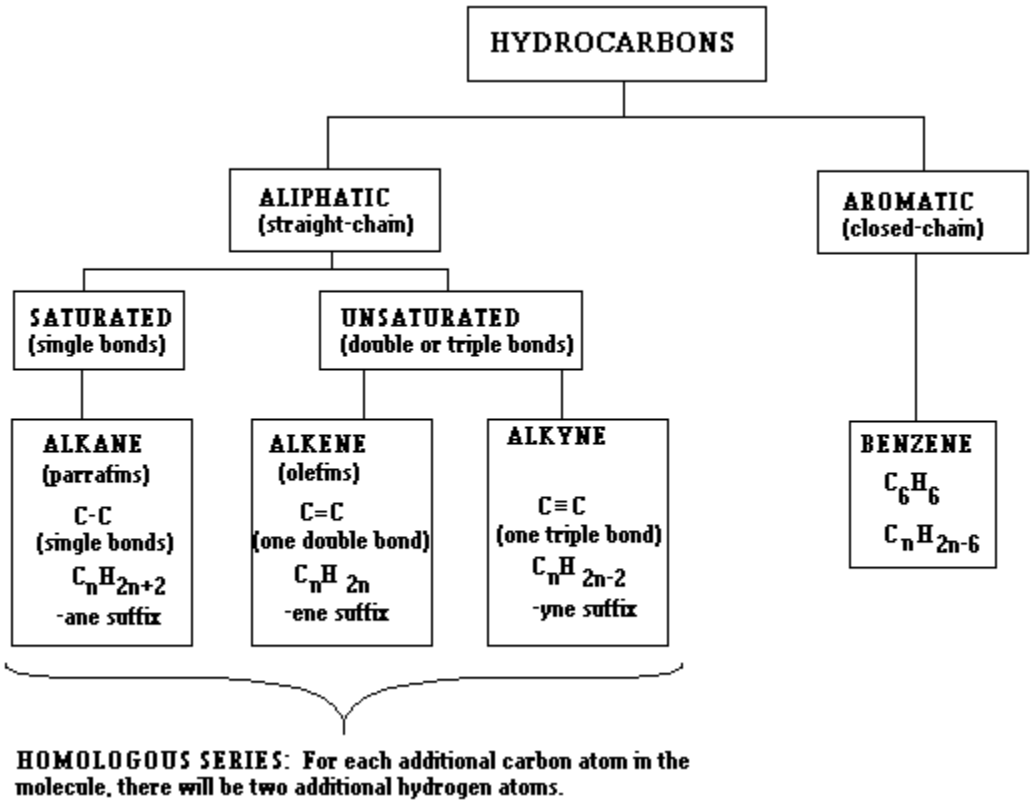
Where did all this oil come from? Bacteria, diatoms, plankton and other ocean organisms have lived and died in our oceans for more than a billion years. As they die, they settle to the ocean bottom, where there is no oxygen to rot the dead organisms. They decompose into a tarry organic goo that got buried by sediment over the eons. The oceans lifted in tectonic upheavals and dried out, leaving behind their salt. These salt flats (like the Bonneville Salt Flats out near Salt Lake City, Utah) have themselves been uplifted, thrown down, buried under new oceans and seas, perhaps to be uplifted yet again, over the course of hundreds of millions of years. All that time the thick, tarry, organic goo soaked into the sedimentary rock became crude oil, sitting under buried salt domes that kept the oil locked safely away for time out of mind.

Humans came and started drilling for this material, which was so useful. They drilled on land (you can see oil derricks and wells as you drive down most roads on the Great Plains of the United States), in the ocean (the Persian Gulf, the North Sea and the Gulf Of Mexico, among others) and as old oil fields ran dry, new ones were found and exploited. There is a limited amount of this goo on the planet, and it is inevitable that it will run out eventually. As we tap the easy sources of oil, more and more difficult-to-reach sources are left. Areas in Canada have soil that is soaked with bitumen, an extremely heavy form of oil, the so-called “tar sands” of Alberta. It requires a lot of excavation to extract even a small amount of petroleum, and it requires pretty extensive refining to get usable fuel out of it. It takes energy to make energy, and the harder it is to get to the oil, the more expensive it gets. A lot of Earth’s oil is found in politically unstable regions, making the prospect of getting to it difficult, and any turmoil in those regions or threat of hurricanes passing over the oil fields in the Gulf of Mexico is enough to destabilize prices and send them soaring.

We will likely be using oil as a source of energy for decades to come. The real key to a sustainable energy future is to find other ways of generating the energy we are so hungry for, and making the machine we have more efficient to operate.

In this topic, you will learn about the three types of hydrocarbons, many of which can be found in crude oil. Keep in mind that these molecules are made up of ONLY hydrogen and carbon. In the topics after this, you will see what happens when you add other elements to these simple organic molecules.

Hydrocarbons Organizational Chart



Prefix table: This information can be found on Reference Table P.

As there are millions of organic compounds, there needed to be a naming system developed to handle all of those compounds. The International Union of Pure and Applied Chemistry (IUPAC, www.iupac.org) is responsible for all chemical nomenclature (naming systems). The names of organic compounds are designed to describe a molecule in terms of:

1) How many carbon atoms are in the longest continuous chain? This gets a prefix, as seen in this chart:

# of Carbons In Molecule	Prefix	Examples
1	Meth-	Methane, methanol, methanal, methanoic acid
2	Eth-	Ethane, ethane, ethyne, ethanol, ethanal, ethanoic acid
3	Prop-	Propane, propene, propyne, propanol, propanal, propanone, propanoic acid
4	But-	Butane, butene, butyne, butanol, butanal, butanone, butanoic acid
5	Pent-	Pentane, pentene, pentyne, pentanol, pentanal, pentanone, pentanoic acid
6	Hex-	Hexane, hexane, hexyne, hexanol, hexanal, hexanone, hexanoic acid
7	Hept-	Heptane, heptene, heptyne, heptanol, heptanal, heptanone, heptanoic acid
8	Oct-	Octane, octane, octyne, octanol, octanal, octanone, octanoic acid
9	Non-	Nonane, nonene, nonyne, nonanol, nonanal, nonanone, nonanoic acid
10	Dec-	Decane, decene, decyne, decanol, decanal, decanone, decanoic acid

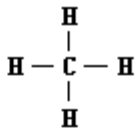
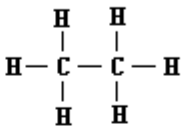
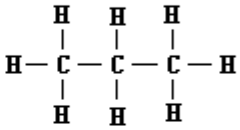
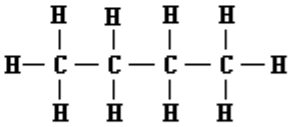
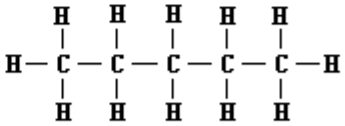
2) What is attached to the longest continuous chain? Are there double or triple bonds? Atoms of chlorine or fluorine? Special groups of atoms called functional groups? Other chains of carbon branching off of the main chain? The next few topics will address this issue.

They say a picture is worth a thousand words. The design of the IUPAC naming system is such that it takes far less than a thousand words to name a specific molecule's structure.

Types of Hydrocarbons: This information can be found on Reference Table Q.

SATURATED HYDROCARBONS: all single bonds between carbons

ALKANE or PARAFFIN FAMILY
Except for methane (the simplest organic molecule), all alkanes consist of chains of carbon atoms linked by single bonds. Used for fuels, raw materials in synthesizing other organic compounds.

FORMULA	Name	Boiling Point	Structural Formula
CH_4	methane	-161 ºC	
C_2H_6	ethane	-89	
C_3H_8	propane	-44	
C_4H_{10}	butane	-0.5	
C_5H_{12}	pentane	36	
C_6H_{14}	hexane	68	Add 1 carbon and 2 hydrogens to the middle of pentane
C_7H_{15}	heptane	98	Add 1 carbon and 2 hydrogens to the middle of hexane
C_8H_{18}	octane	125	Add 1 carbon and 2 hydrogens to the middle of heptane
C_9H_{20}	nonane	151	Add 1 carbon and 2 hydrogens to the middle of octane
$C_{10}H_{22}$	decane	174	Add 1 carbon and 2 hydrogens to the middle of nonane

As you can see, as the molecule gets larger, the boiling point increases. This is due to increasing London dispersion force strength!

The general formula is C_nH_{2n+2}. This means that if the number of carbon atoms is known, doubling that number and adding two will give the number of hydrogen atoms in the molecule.

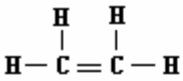
What is the molecular formula of octane?

Octane has 8 carbon atoms (from the prefix *oct*). Double 8 and add two and this gives 18 hydrogen atoms. The formula is therefore

$$\mathbf{C_8H_{18}}$$

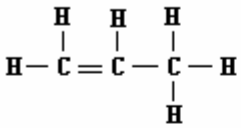
UNSATURATED HYDROCARBONS: at least one double or triple bond between carbons

ALKENE FAMILY (OLEFINS)
A homologous series of hydrocarbons, one differing from the next by a $-CH_2-$. Contains one carbon-carbon double bond somewhere along the chain. Molecules of butene and larger allow for placement of double bond at different locations along the chain. These are called **ISOMERS, or molecules with the same molecular formula but different structural formula.** The lowest-numbered carbon touching the double bond is identified as in the examples below:



Ethene: 2 carbons with a double bond between them. Each carbon fills its remaining two bonds with hydrogens.

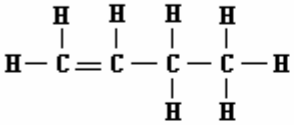
C_2H_2



Propene: 3 carbons with a double bond between the end carbon and the middle carbon.

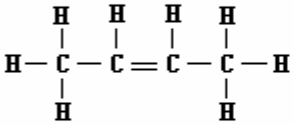
C_3H_6

The two isomers of BUTENE



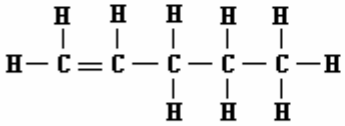
1-butene: there is a double bond between the end carbon (the 1st carbon) and the 2nd carbon. The number 1- indicates that the 1st carbon is the lowest numbered carbon that the double bond is touching.

C_4H_8

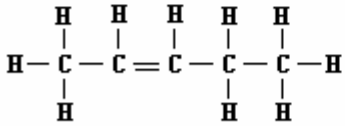


2-butene: there is a double bond between the two middle (2nd and 3rd) carbons. The number 2- indicated that the 2nd carbon is the lowest numbered carbon that the double bond is touching.

The two isomers of PENTENE

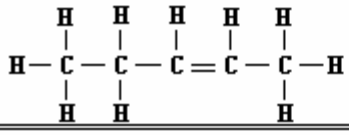


1-pentene: there is a double bond between the 1st and 2nd carbons.



2-pentene: there is a double bond between the 2nd and 3rd carbons.

C_5H_{10}



Also 2-pentene. Count the carbons from the side the double bond is closest to. In this case, it's the right side, and the double bond is between the 2nd and 3rd carbons.

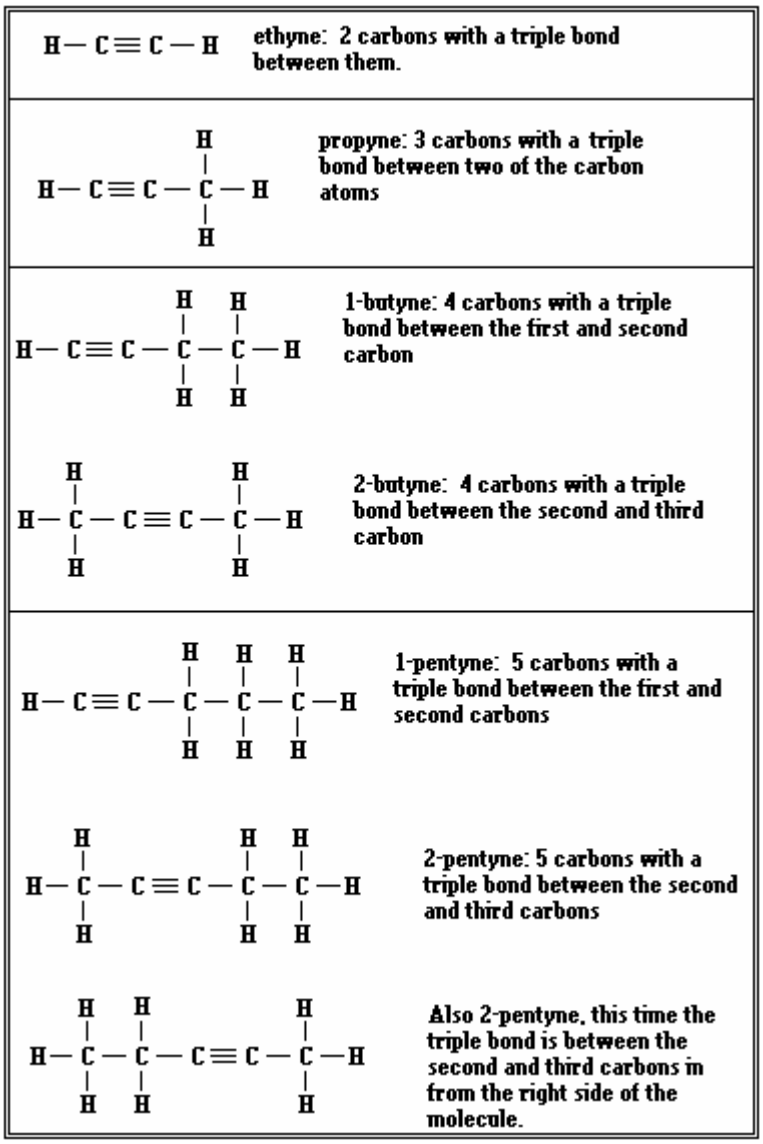
The general formula is C_nH_{2n}. This means that if the number of carbon atoms is known, doubling that number will give the number of hydrogen atoms in the molecule.

What is the molecular formula of octene?

Octene has 8 carbon atoms (from the prefix *oct*). Double 8 and this gives 16 hydrogen atoms. The formula is therefore

$$\mathbf{C_8H_{16}}$$

ALKYNE FAMILY
A homologous series of hydrocarbons, one differing from the next by a $-CH_2-$. Contains one carbon-carbon triple bond somewhere along the chain. Like alkenes, alkynes with four or more carbons can form isomers, with the number of carbons and oxygens being the same, but the triple bond being in different positions.



C_2H_2

C_3H_4

The two isomers of BUTYNE

C_4H_6

The two isomers of PENTYNE

C_5H_8

The general formula is C_nH_{2n-2}. This means that if the number of carbon atoms is known, doubling that number and subtracting two will give the number of hydrogen atoms in the molecule.

What is the molecular formula of octyne?

Octyne has 8 carbon atoms (from the prefix *oct*). Double 8 and subtract two and this gives 14 hydrogen atoms. The formula is therefore

$$\mathbf{C_8H_{14}}$$

Topic 2) Substituted Hydrocarbons (HW: p. 26-27)

Essential Questions: Why is it important for there to be global standards for chemical formulas and naming? How can you make a picture worth a lot less than a thousand words?

There are millions of organic compounds. Isomers of alkanes, alkenes and alkynes account for many organic compounds, but we have just skimmed the surface of the huge, gooey pond that is Organic Chemistry. Hydrocarbons can be built that branch off on the middle (alkyl groups) or have other atoms than hydrogen bonded to the carbons. One common kind of element to have in place of hydrogen is a halogen (Group 17) atom. When a halide is bonded to the molecule, the molecule is no longer a hydrocarbon. It is a **halocarbon**, or an **alkyl halide**. How to draw and name these molecules, as well as how the halide got on to the molecule to begin with, are all topic that will be covered here.

IUPAC (International Union Of Pure And Applied Chemistry) NAMING SYSTEM

1) The number of carbons in the longest continuous unbroken chain is used to determine the prefix of the parent name.

2) The position of any functional group on the longest chain is used for two purposes:
   a) determines the direction of numbering for the carbons. Functional group is on the lowest possible numbered carbon.
   b) determines the suffix of the parent name.

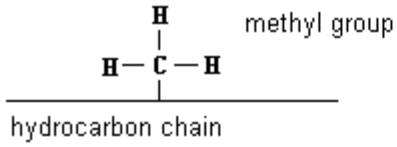
3) The position of any alkyl group is considered next. In the absence of a functional group (alkanes), the alkyl group gets priority in the numbering.

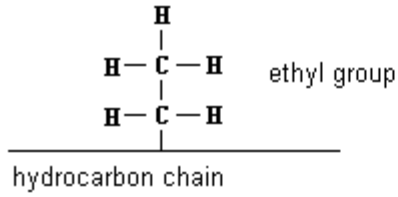
4) When two or more identical alkyl groups are present on the hydrocarbon chain, their number is specified by the Greek prefixes di- (2), tri- (3), tetra- (4), and so on. The position is also specified.

5) When different alkyl groups are present on the chain, they are given in alphabetical order. (ethyl-methyl)

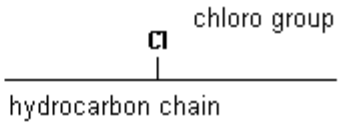
6) When halide groups are on the chain, their names, number and position are considered last, listed in alphabetical order.

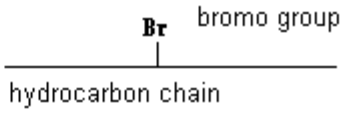
ALKYL GROUPS: alkane molecule fragments bonded to a hydrocarbon chain

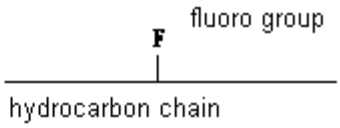


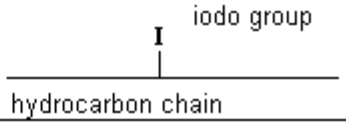


HALIDE GROUPS: halogen atoms bonded to a hydrocarbon chain

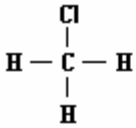






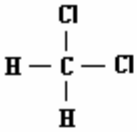


EXAMPLE MOLECULES AND NAMING OF SUBSTITUTED HYDROCARBONS



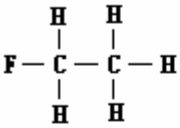
One carbon = methane
One chloro group attached to it

chloro methane



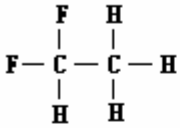
One carbon = methane
Two chloro groups attached = dichloro

dichloro methane



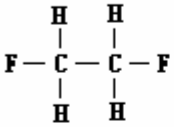
Two C's single bonds = ethane
One fluoro group attached

fluoro ethane



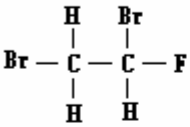
Two C's single bonds = ethane
Two fluoro groups = difluoro
Both F's on the end carbon

1,1 difluoro ethane



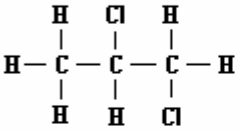
2 C's w/ single bond = ethane
2 F's attached, on on the 1st and one on the 2nd carbon

1,2 difluoro ethane



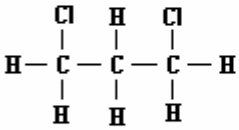
2 C's w/ single bond = ethane
2 Br's, one on the 1st and one on the 2nd = 1,2 dibromo
1 F on the end carbon

1 fluoro 1,2 dibromo ethane



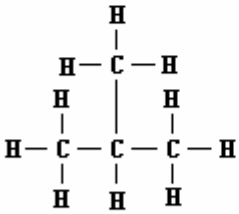
3 carbons, single bonded = propane
2 chloro groups, one on the 1st and one on the 2nd carbon

1,2 dichloro propane



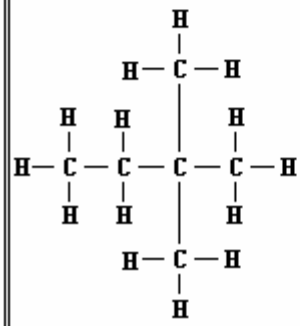
3 carbons, single bonded = propane
2 chloro groups, on on the 1st and one on the 3rd carbon

1,3 dichloro propane



3 carbons, single bonded = propane
1 methyl group on the middle carbon

2 methyl propane



Four carbons single bonded = butane
Two methyl groups, both bonded to the second carbon in on the right side

2,2 dimethyl butane

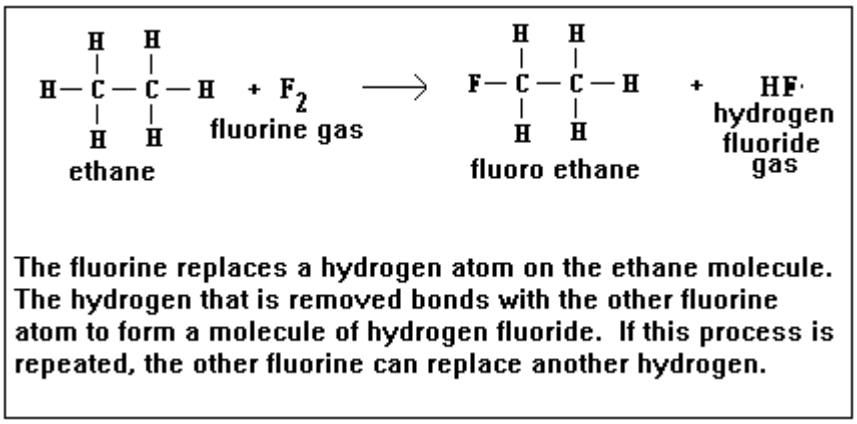
The more carbons a molecule has, the more possible isomers can be formed of that molecule.

HOW DID THE HALIDE GROUPS GET ON TO THE HYDROCARBON CHAIN TO BEGIN WITH?

Addition and Substitution Reactions

Hydrocarbons undergo two simple kinds of reactions, the products of which are called hydrocarbon derivatives, hydrocarbon substitution products, or substituted hydrocarbons.

1) Substitution Reactions



If a saturated hydrocarbon (alkane) is reacted with a halogen, the one of the halogen atoms replaces a hydrogen on the hydrocarbon chain. **The hydrogen replaced is almost always the ones that are on the end of the hydrocarbon molecule.** Other isomers are also possible, but less common.

The hydrogens get replaced **ONE AT A TIME.**

The reactive halogen atoms **substitute** for hydrogen atoms, hence the name.

Examples using molecular formulas:

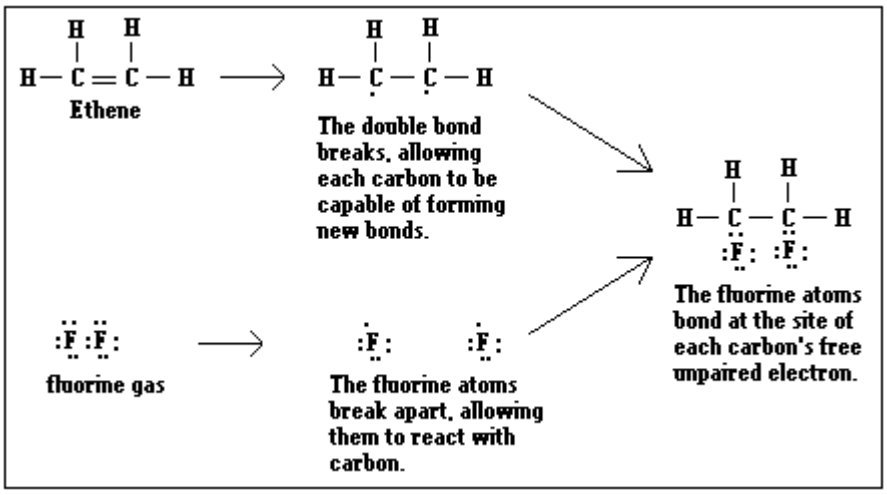
$C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$ ← One chlorine atom replaces a hydrogen atom.

$C_4H_{10} + HBr \rightarrow C_4H_9Br + H_2$ ← the bromine atom replaces one hydrogen atom

2) Addition Reactions

If an unsaturated hydrocarbon (alkene or alkyne) is reacted with a halogen, the mechanism of the reaction is such that the **multiple bond is broken, and the halogen adds on at the site of the newly available bonds.**

This diagram shows how the bond breaks, using dot diagrams. The next diagram will show the addition reaction using only structural formulas.

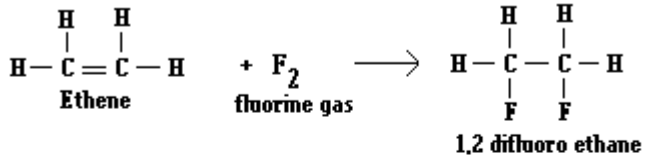


Examples using molecular formulas:

$C_3H_6 + Cl_2 \rightarrow C_3H_6Cl_2$ ← the chlorine adds to the molecule.

$C_4H_8 + HBr \rightarrow C_4H_9Br$ ← the bromine and hydrogen atoms add to the molecule.

Addition Reactions, Continued



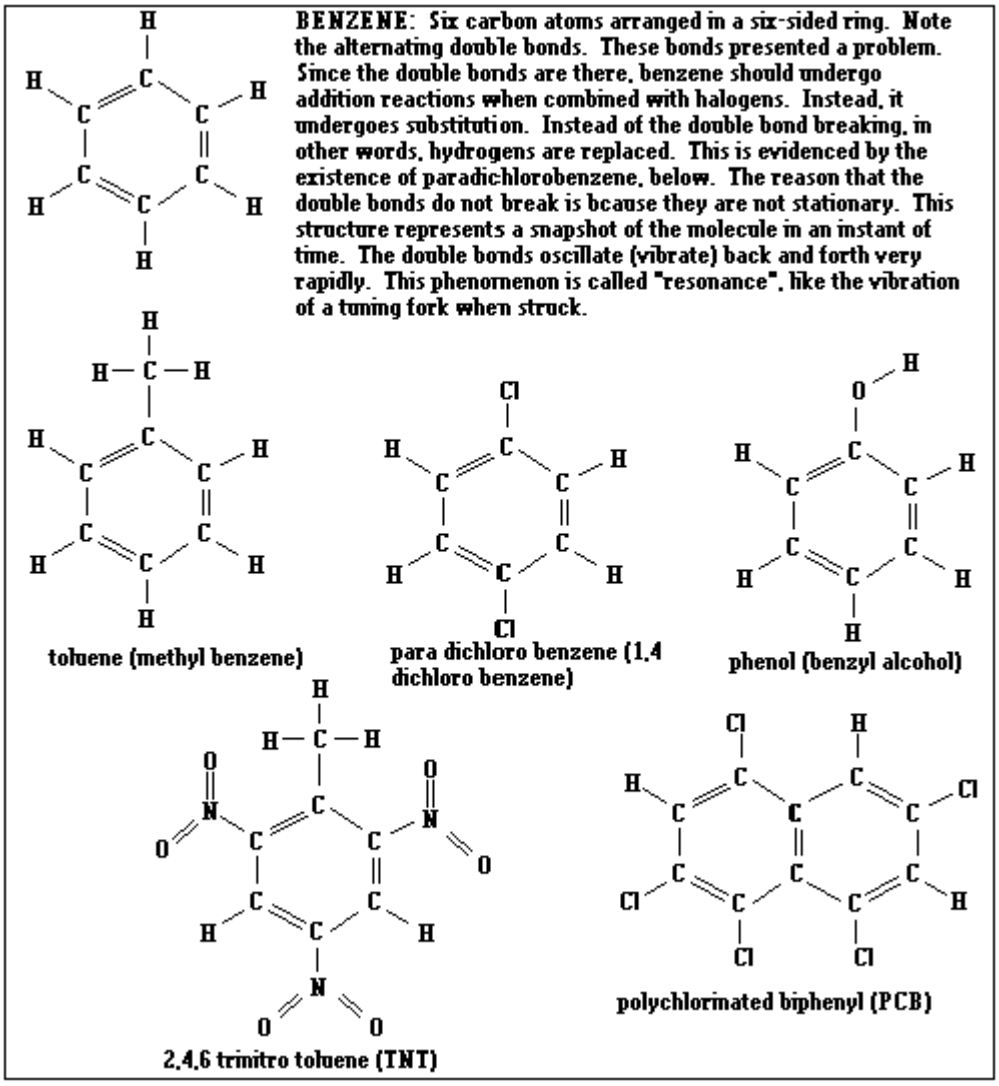
The fluorine atoms have a choice: to replace hydrogen or break the double bond. They will do whatever takes less energy to do, and in this case, breaking one of the double bonds takes less energy. Because each bond in a double bond is "stretched", each one has slightly less strength than a normal single bond. It is easier to break one of the C=C bonds than to break a C-H bond. When the double bond breaks down to a single bond, it frees up one electron in each carbon to form another bond. The fluoring atoms ADD to the site of the double broken bond, one on one carbon, one on the other.

Addition reactions are used when you need to make a molecule where halogen atoms are on adjacent (next to each other) carbons. If you want to make 1,4 dichloro butane, use substitution. If you want to make 2,3 dichloro butane, then addition is the reaction for you!

AROMATIC HYDROCARBONS

Aromatic Hydrocarbons - cyclic hydrocarbons that possess a bonding phenomenon called resonance.

Benzene: C_6H_6: the basis of most aromatic compounds.



Topic 3) Of Functional Groups and Families (HW: p. 28-29)

Essential Questions: Why is it important for there to be global standards for chemical formulas and naming? How can you make a picture worth a lot less than a thousand words?

To this point, you have become familiar with hydrocarbons, branched hydrocarbons and halocarbons. There are other "families" of organic compounds, the more common of which may be found on Reference Table R. These molecules contain a "functional group", a group of atoms in a particular position on the molecule, that gives the molecule very special properties and allows one to identify an organic compound. You have to be very careful…many families look quite similar, sharing the same functional group, and it might be the placement of where the functional group is that makes the difference as to which family the molecule belongs to. Most of these functional groups contain oxygen, and a couple contain nitrogen. There are other functional groups than the ones laid before you here, but these are the only ones you will be responsible for here.

ALCOHOLS - hydrocarbons with a substituted hydroxyl group (-**OH**) as their functional group.

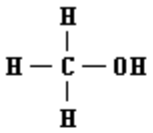
Properties

1) The -OH group makes the molecule polar as a highly electronegative end. The smaller alcohols are soluble in water.
2) The -OH is covalently bonded, and does not dissociate in water. Therefore, alcohols are not bases.

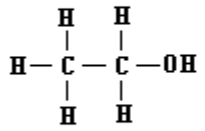
Naming of alcohols - the same as naming any other hydrocarbon. The suffix of the parent name is -ol, and the position of the -OH group on the chain is indicated by the lowest-numbered carbon.

Types of alcohols:

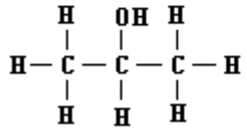
Monohydroxy - containing 1 -OH



Methanol (wood alcohol, methyl alcohol): a one-carbon alcohol. This is the most polar alcohol molecule and therefore is most readily miscible with water. It is also extremely poisonous.

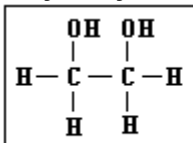


Ethanol (grain alcohol, ethyl alcohol): a two-carbon alcohol. This is the alcohol found in alcoholic beverages. Though not as deadly as methanol, it is still poisonous.



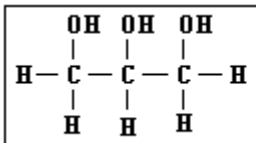
2-propanol (isopropyl alcohol, rubbing alcohol): a three-carbon alcohol with its hydroxyl group bonded to the center (second) carbon. Commonly found in most bathroom cabinets.

Dihydroxy - containing 2 -OH



1,2 ethandiol (ethylene glycol, antifreeze): a two-carbon dihydroxy alcohol with hydroxyl groups on the first and second carbons. This poisonous nonelectrolyte is the basis of antifreeze. It is deadly to pets and children because it is sweet-tasting yet deadly.

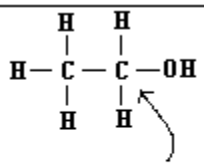
Trihydroxy - containing 3 -OH



1,2,3 propantriol (glycerol, glycerin): a three-carbon trihydroxy alcohol with hydroxyl groups on each carbon. This alcohol is generally nontoxic and can be found in foods. It is also used as a laboratory lubricant.

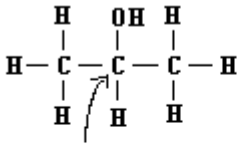
Positioning of Functional Group

If the functional group is on a carbon bonded only to one other carbon or no other carbons, it is called **primary**.



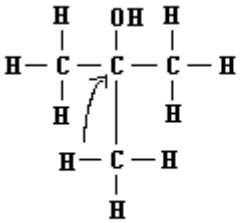
Primary Carbon: The hydroxyl group is bonded to the end carbon in this molecule. The end carbon is a PRIMARY carbon.

If the functional group is bonded to a carbon that is bonded to 2 other carbons, the functional group is on a **secondary** carbon.



Secondary Carbon: The hydroxyl group is bonded to the middle carbon in this molecule. The middle carbon is a SECONDARY carbon.

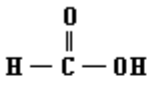
If the functional group is bonded to a carbon that is bonded to 3 other carbons, the functional group is on a **tertiary** carbon.



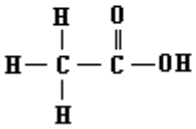
Tertiary Carbon: The hydroxyl group is bonded to a middle carbon with a methyl group bonded to it. This carbon is directly bonded to three other carbon atoms, making it a TERTIARY carbon.

ORGANIC ACIDS

a) Functional group –COOH, drawn as R – **C - O**H **(primary carboxyl group, -COO**-)
b) The H on the end dissociates in water.
c) The shorter the R (attached hydrocarbon chain, called a *radical*), the stronger the acid.
d) Parent name suffix -oic acid. All carboxyl groups are on primary carbons.



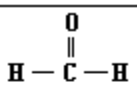
Methanoic Acid (formic acid): a one-carbon organic acid. Responsible for the pain caused by fire ant bites.



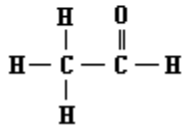
Ethanoic Acid (acetic acid): a two-carbon organic acid. A 5% solution of this acid in water is commonly known as vinegar. The H on the rightmost side is the one that ionizes when dissolved in water.

ALDEHYDES

a) Functional group R-**CHO**, drawn as R- **C** - H **(primary carbonyl group, -CHO)**
b) Parent name suffix -al. Carbonyl group on **primary** carbon.



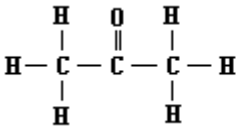
Methanal (formaldehyde): a one-carbon aldehyde. Used to preserve biological specimens and as a glue to hold the layers of plywood and oriented strand board together.



Ethanal (acetaldehyde): a two-carbon aldehyde.

KETONES

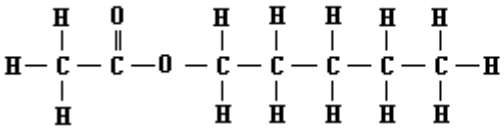
a) **secondary** form of aldehydes
b) secondary carbonyl group (R_1-**CO**-R_2), drawn as R_1 – **C** - R_2. R_1 and R_2 are hydrocarbon chains of at least one carbon.
c) Parent name suffix -one. Indicate positioning of carbonyl group on lowest numbered carbon.



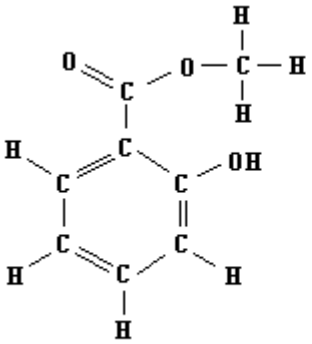
Propanone (acetone): a three-carbon ketone. Used as a solvent in nail polish and is also used for nail polish remover. It is an excellent solvent.

ESTERS

a) Formed by a carboxyl group surrounded by 2 alkyl groups (R_1-**COO**-R_2)
b) Responsible for odors and flavors of plants, fruits and flowers.
c) Can be synthesized to make artificial flavors and fragrances.



Pentyl ethanoate (amyl acetate, banana oil): synthesized by reacting pentanol with ethanoic acid. Found in any candy that contains artificial banana flavoring. It is produced naturally by bananas as they over-ripen.



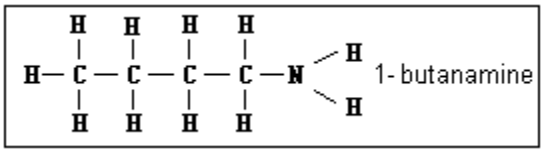
Methyl salicylate (oil of wintergreen): made of phenol with a carboxyl group attached to it and a methyl group further attached to that. Synthesized from methanol and salicylic acid, which is the basis for naming this ester.

methanol --> methyl
salicylic acid --> salicylate

Found in wintergreen flavored candy and gum, as well as muscle relaxant creams and breath fresheners.

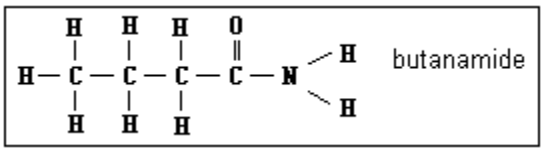
AMINES

a) Formed by a nitrogen atom with three attached radicals. In this class, it will be represented as $R\text{-}NH_2$.
b) Suffix -amine
c) Use number in front of name to indicate position of amine group if the molecule has three or more carbons.



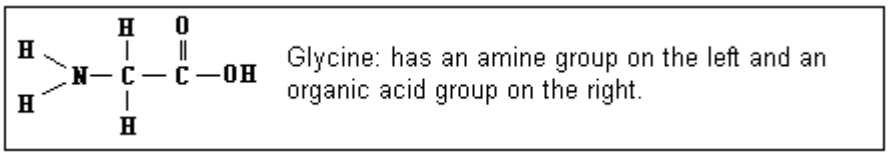
AMIDES

a) Primary $CONH_2$
b) Suffix –amide



AMINO ACIDS

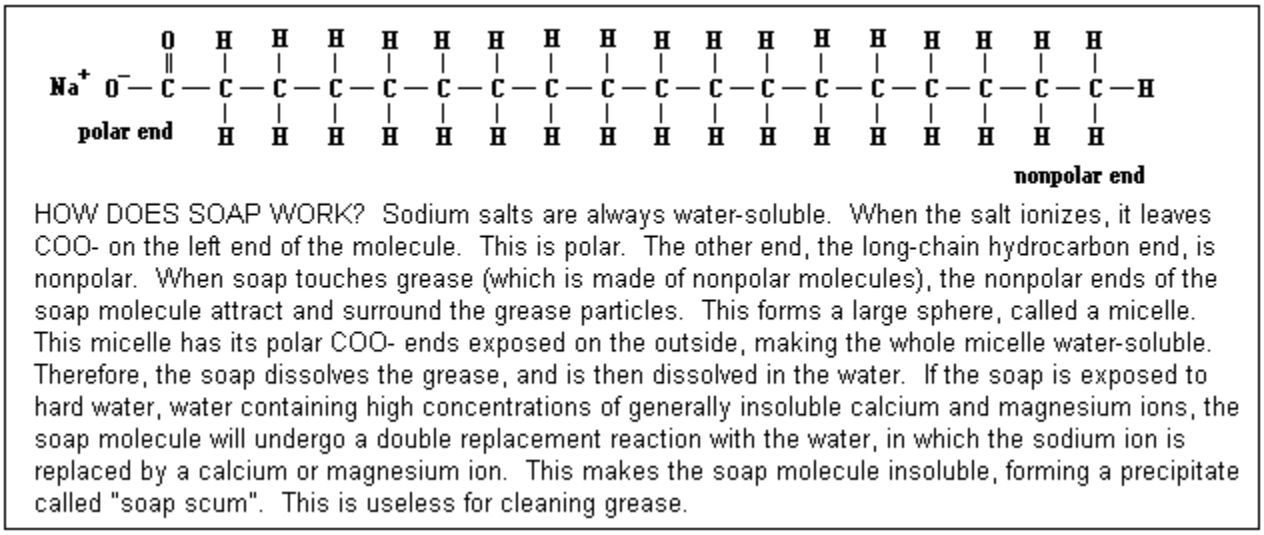
a) Contains an amine group on one end of the molecule a carboxyl (acid) group on the other end of the molecule.
b) Forms the building blocks of life, including proteins, DNA and RNA.



SOAP

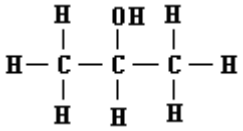
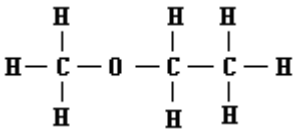
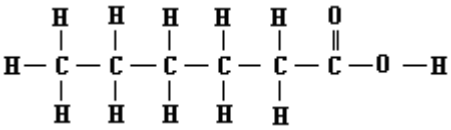
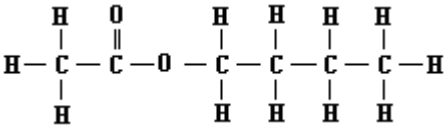
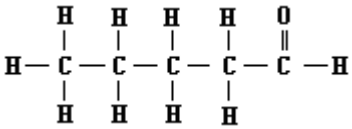
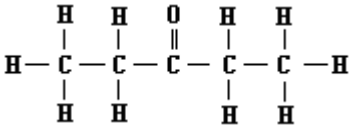
a) A sodium or potassium salt of a fatty acid.
b) Formed by the reaction of a strong alkali (base) with fat.

$C_{17}H_{35}COONa$: Sodium Stearate



ISOMERS

Because families might share functional groups, those that do are isomers of each other. Alcohols and ethers both have one oxygen. Organic acids and esters both share carboxyl groups (COO). Aldehydes and ketones both share carbonyl groups (C=O). The only difference between the families that share functional groups is the positioning of that group. For example, ketones have a secondary carbonyl (C=O in the middle) and aldehydes have a primary carbonyl (C=O at the end).

Isomers	Example	Isomer of Example
Alcohols and Ethers	 **2-propanol (C_3H_8O)**	 **Methyl ethyl ether (C_3H_8O)**
Organic Acids and Esters	 **Hexanoic acid ($C_6H_{12}O_2$)**	 **Butyl ethanoate ($C_6H_{12}O_2$)**
Aldehydes and Ketones	 **Pentanal ($C_5H_{10}O$)**	 **3-pentanone ($C_5H_{10}O$)**

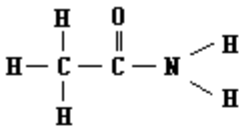
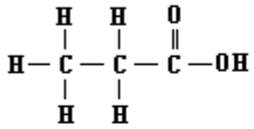
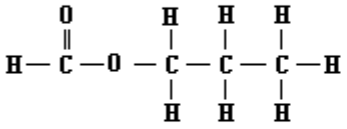
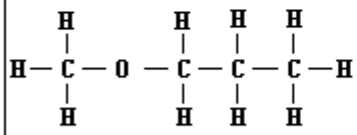
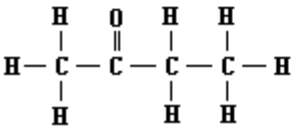
SO…WHAT DO <u>YOU</u> HAVE TO BE ABLE TO DO?

1) Be able to recognize what family a particular molecule belongs to. More examples are given on Reference Table R.

2) Be able to name simple examples of each kind of family. You will learn more about the naming of esters tomorrow, and you are not responsible for naming soaps or amino acids.

3) Be able to draw isomers of the various groups (alcohols are isomers of ethers, organic acids are isomers of esters, ketones are isomers of aldehydes)

<u>Examples:</u>

	Identify Family: Amide. It contains $CONH_2$ on the end. Name: Two carbons = ethanamide
	Identify Family: Organic Acid. It contains COOH on the end. Name: Three carbons = propanoic acid
	Identify Family: Ester. It has COO in the middle of the molecule. Name: propyl methanoate (more about that tomorrow)
	Identify Family: Ether. It has O between two hydrocarbon chains. Name: methyl propyl ether. To the left of the O is methyl (1 C) and to the right of the O is propyl (3 C's).
	Identify Family: Ketone. It has a CO in the middle of the molecule (secondary). Name: 4 carbons = butanone

Topic 4) Organic Reactions (HW: p. 30-31)

Essential Question: How do such wonderfully complex molecules such as those responsible for life come into being?

<u>These reactions just scratch the surface of the amazing universe of organic reactions.</u>

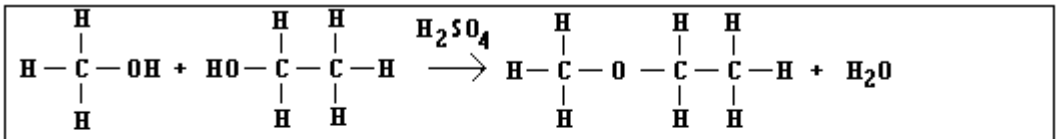
<u>Dehydration Synthesis</u>

The linking of two organic compounds by removing water from functional groups.

1) Etherification

a) requires 2 alcohols

b) H_2SO_4 is the dehydrating agent. It removes H from one alcohol molecule and OH from the other to form H_2O.



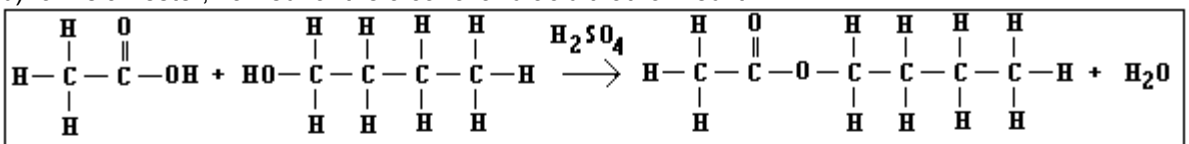
Methanol + Ethanol methyl ethyl ether

The sulfuric acid removes H from methanol and OH from ethanol. The two molecules join together at the site of the removal to form an ether

2) Esterification

a) requires an alcohol and a carboxylic acid

b) forms an ester, named for the alcohol and acid that formed it.



Ethanoic acid + 1-butanol butyl ethanoate

The sulfuric acid removes the H from the acid and the OH from the alcohol to make water. The two molecules join at the site of the removal. The name is derived

The sulfuric acid removes the H from the acid and the OH from the alcohol to make water. The two molecules join at the site of the removal. The name is derived from the two reactants: butanol becomes butyl, ethanoic acid bcomes ethanoate. Therefore, the name of esters can be accomplished by the following format:

(name of alcohol with -anol replaced with -yl) (name of acid with -ic acid replaced with -ate)

Examples: Methanol and salicylic acid forms methyl salicylate, pentanol and ethanoic acid forms pentyl ethanoate.

<u>Fermentation</u>

Fermentation of glucose or fructose in corn, barley, grapes, apples, etc. forms ethanol:

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2\ CH_3CH_2OH + 2\ CO_2$$

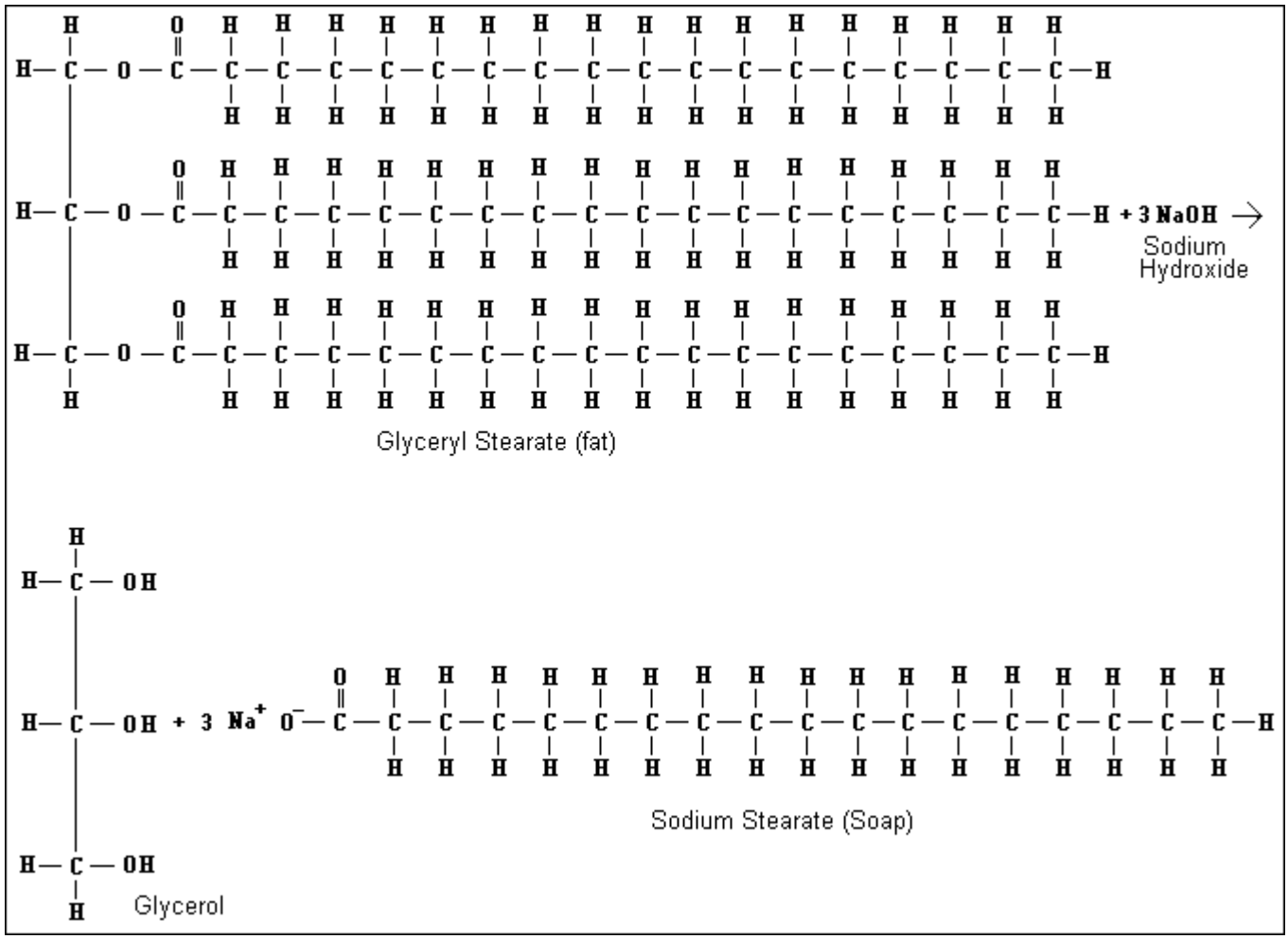
The reaction proceeds until the alcohol content reaches 13%, at which point the yeast dies. Further increases in concentration may be yielded by distillation. Used in alcoholic beverages where, in the synthesis of acetic acid (by catalytic oxidation) and it is used as a solvent.

Saponification

The production of soap.

a) Requires a glycerol ester (fat) and sodium hydroxide (strong base)
b) The glycerol ester is dissolved in ethanol, and the NaOH is mixed in.
c) The mixture is heated slowly until it thickens.
d) The alcohol solvent is now evaporated off.
e) The resultant mixture is glycerol plus the sodium salts of the long-chain acids. The salts represents the soap.
f) The salts may be precipitated out of the glycerol by adding NaCl and filtering out the glycerol. The resulting lump is soap.

glyceryl stearate + 3 NaOH -----> glycerol + sodium stearate
$(C_{17}H_{35}COO)_3C_3H_5$ $C_3H_5(OH)_3$ $C_{17}H_{35}COONa$



Polymerization

POLYMER - an extremely large molecule made by connecting many smaller molecules together. The basic molecules used as "building blocks" of the polymer are called monomers.

Monomer molecule = A

polymerization
18 A ----------> A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A

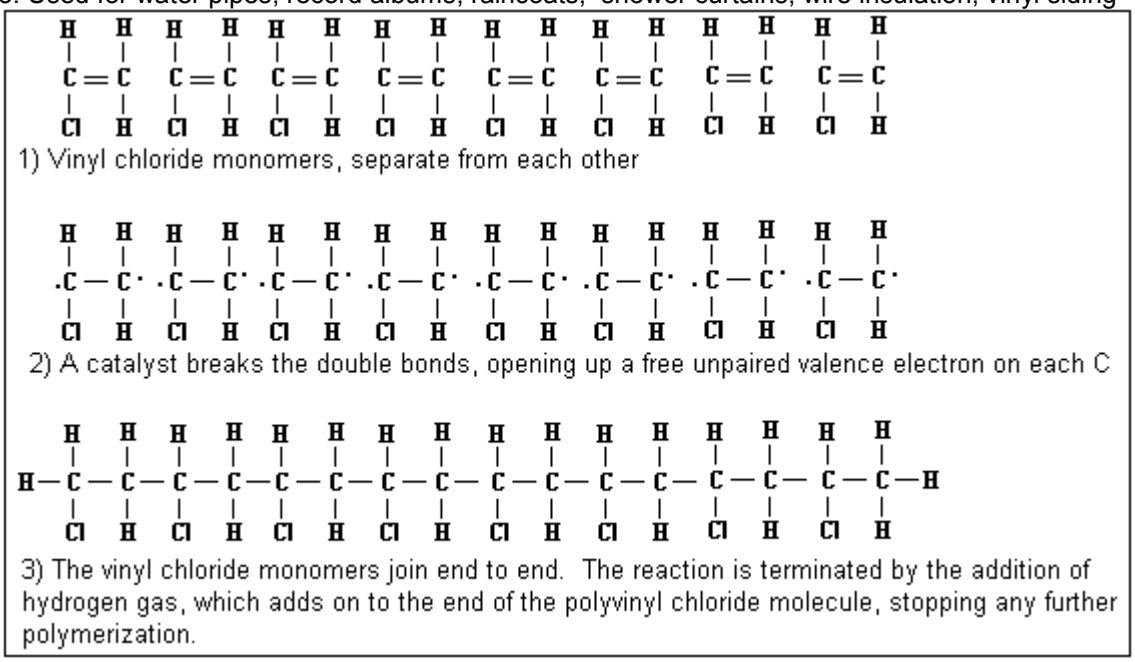
Can be abbreviated as 18 A → $-(-A-)-_{18}$, which represents a chain of A monomers 18 units long.

Types of Polymers:

1) Addition Polymers - formed by addition polymerization reaction: the monomer's double bond opens, allowing the monomer units to join end to end. The name of the polymer is found by putting a "poly" in front of the monomer's name. For example, propylene monomer forms polypropylene.

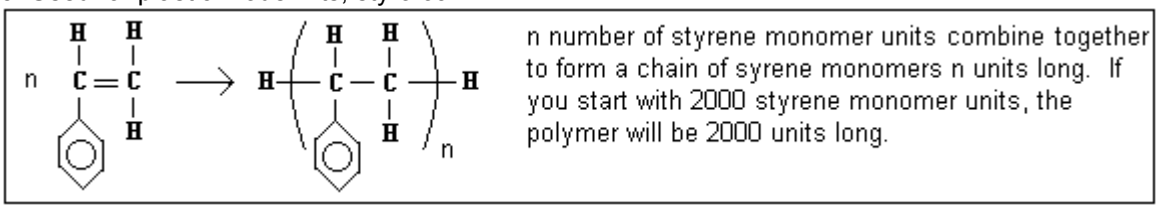
a) Polyvinyl Chloride

1. Formed from Vinyl Chloride monomer (chloro ethane)
2. The double bond breaks, and VC monomer units join end to end.
3. Used for water pipes, record albums, raincoats, shower curtains, wire insulation, vinyl siding



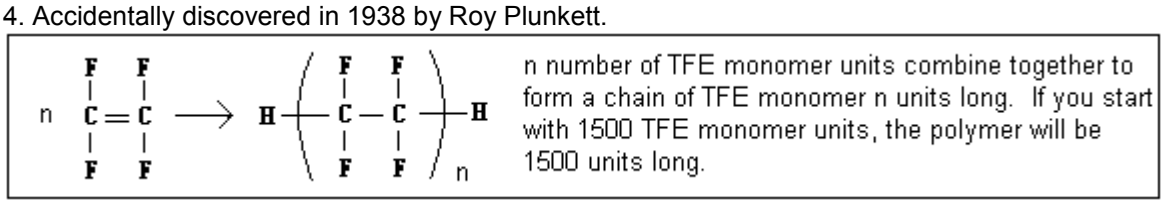
b) Polystyrene

1. Formed from styrene monomer (phenyl ethane, basically ethene with a benzene attached to it)
2. The double bond breaks, and styrene monomer units join together.
3. Used for plastic model kits, styrofoam



c) Polytetrafluoroethene (teflon)

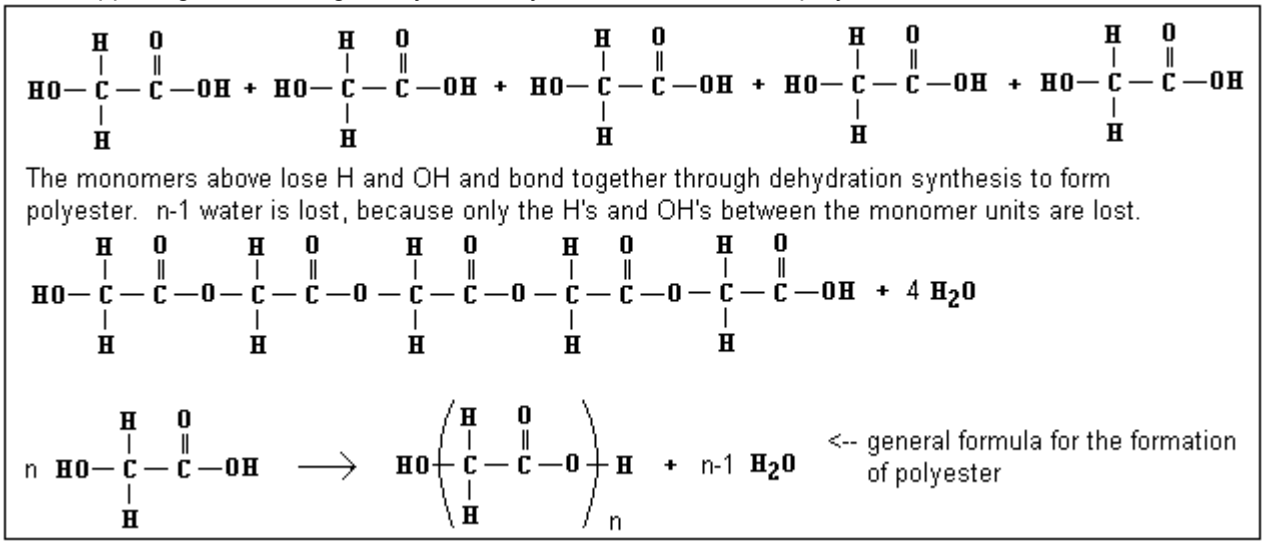
1. Formed from tetraflouro ethene monomer
2. The double bond breaks, and TFE monomer units join together.
3. Used for no-stick pans.
4. Accidentally discovered in 1938 by Roy Plunkett.



2) Condensation Polymers - formed by dehydration synthesis of difunctional monomer units. H and OH are removed from the ends of the monomer units, allowing them to join together. Water is given off as a byproduct.

Polyester

1. Formed from monomer units that have an alcohol functional group on one end and a carboxylic acid functional group on the other end.
2. The opposing ends undergo dehydration synthesis, and form the polymer.



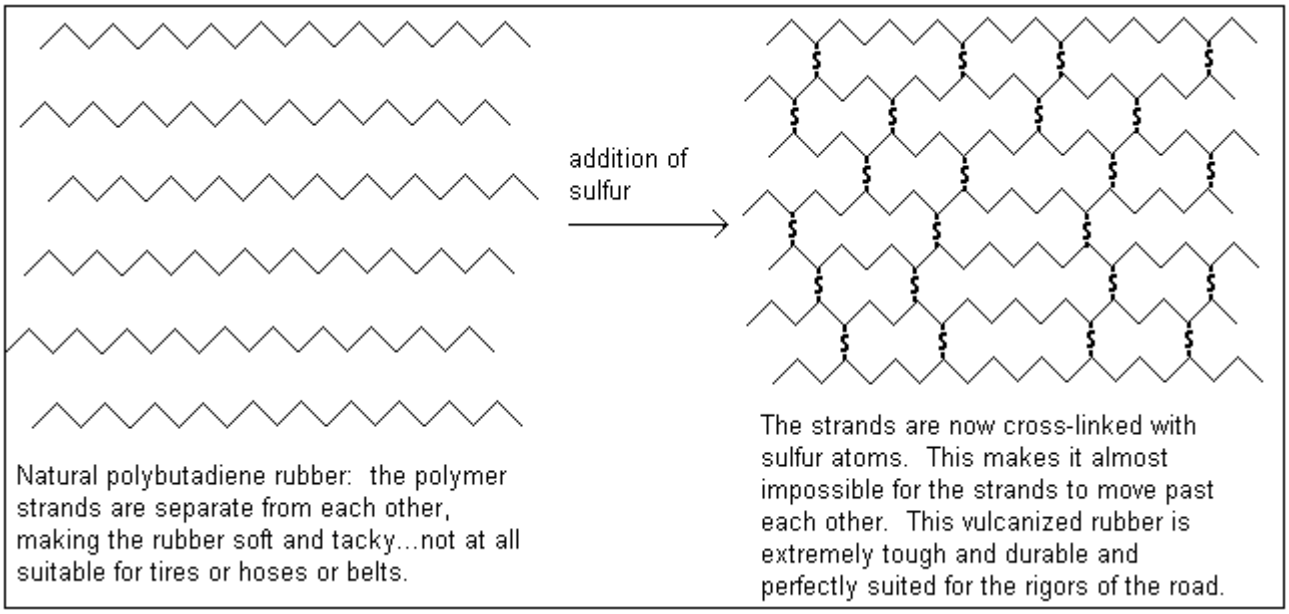
3) Rubber

a) cis- Polyisoprene (tires), polybutadiene (tires), polychloropropene (Neoprene...wire covering, automotive drive belts, wetsuit material)), Nitrile (automotive hoses and gaskets)

1. Formed by addition polymerization

2. The resultant macromolecule is tacky and not very strong. It generally has a low melting point.

3. In order to make this stuff serviceable, it must by toughened up. This is done by a process whereby the polymer chains are cross-linked with sulfur. This toughens up the rubber. This process was discovered accidentally by Charles Goodyear in 1839. This process is called **vulcanization.**
Unfortunately, when heat is applied to rubber so treated, it does not melt, but burns, releasing CO, CO_2 and SO_2.



SO…WHAT DO YOU HAVE TO BE ABLE TO DO?

1) Recognize a reaction when you see it:

Reaction	Type	How do you know?
$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$	Combustion	An organic compound is reacted with oxygen, forming CO_2 and H_2O.
$C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$	Substitution	A Cl takes the place of one of the H's in the hydrocarbon.
$C_6H_{12}O_6 \rightarrow 2\ CO_2 + 2\ C_2H_5OH$	Fermentation	Sugar forms ethanol.
$C_3H_6 + Cl_2 \rightarrow C_3H_6Cl_2$	Addition	No hydrogen atoms were removed, the chlorines just added to the propene molecule.
$CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O$	Esterification	An ester is formed (COO in the middle).
$CH_3OH + CH_3CH_2OH \rightarrow CH_3OCH_2CH_3 + H_2O$	Etherification	An ether is formed (O in the middle).
$5000\ C_2H_4 \rightarrow -(-C_2H_4-)-_{5000}$	Polymerization	A polymer is formed.

2) Determine the reactants needed to make a particular product:

Desired product	Reaction needed to make it	Reactants needed to make it
Ethanol	Fermentation	Sugar (glucose or fructose) and yeast
1,5 difluoro pentane	Substitution (puts the F's on the ends of the molecule).	Pentane and diatomic fluorine
2,3 difluoro pentane	Addition (puts the F's next to each other in the molecule).	1-pentene (the bond between the 1st and 2nd carbons breaks) and diatomic fluorine
Ethyl propanoate	Esterification (makes an ester)	Ethanol and propanoic acid
Methyl propyl ether	Etherification (makes and ether)	Methanol and propanol
Polyisoprene	Polymerization	isoprene

Student Name:_____ Grades: _____, _____, _____, _____
HydroC HC Subst Families Reactions

1) Introduction To Organic Chemistry Homework

A) Multiple Choice and Short-Answer Questions

_____1) Which of the following compounds is formed by covalent bonding?
a) Na_2S b) $AlCl_3$ c) $C_6H_{12}O_6$ d) LiH

Explain:_____

_____2) Which of the following molecules contains a nonpolar covalent bond?
a) H_2O b) HF c) F_2 d) NH_3

Explain:_____

_____5) Which of the following molecules is polar?
a) F_2 b) NH_3 c) O_2 d) Cl_2

Explain:_____

_____6) Which of the following molecules has the strongest London dispersion force attractions?
a) CH_4 b) C_2H_6 c) C_3H_8 d) C_4H_{10}

Explain:_____

_____7) Which of the following nonpolar molecules has the lowest boiling point?
a) CH_4 b) C_2H_6 c) C_3H_8 d) C_4H_{10}

Explain:_____

_____8) Which of the following substances is organic?
a) NaCl b) NH_3 c) CH_4 d) H_2O

Explain:_____

_____9) Which of the following substances is insoluble in water?
a) NaCl b) NH_3 c) CH_4 d) H_2O

Explain:_____

10) When 2 carbon atoms form a double bond, how many pairs of e^- will be shared between them?_____

11) An organic compound is heated in the presence of oxygen. If a high enough temperature is reached, what chemical reaction will take place?

_____

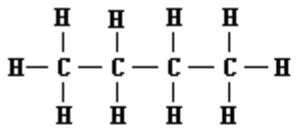
12) An alkane has 5 carbon atoms. How many hydrogen atoms will it have?_____

13) An alkene has 3 carbon atoms. How many hydrogen atoms will it have?_____

14) An alkyne has 4 carbon atoms. How many hydrogen atoms will it have?_____

B) Name the following compounds:

1)



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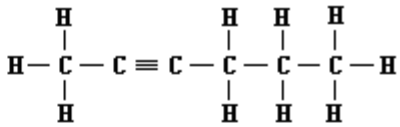
2)



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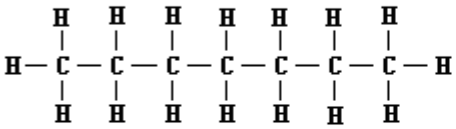
3)



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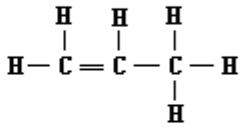
4)



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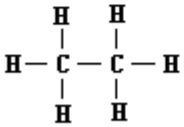
5)



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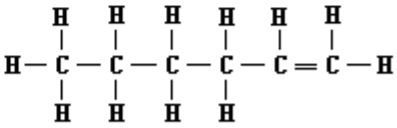
6)



_____

7) C_2H_6 _____ 8) C_3H_4 _____ 9) C_4H_8 _____

C) Draw the following compounds:

1) ethane

2) 1-butene

3) propyne

4) pentane

5) 2-hexene

6) 2-pentyne

ANSWER D and E in complete sentences.

D) Explain in detail what each part of the name 3-heptene means.

E) Why is it necessary for the names to be so specific when naming organic compounds?

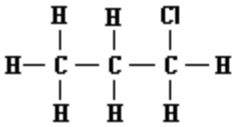
F) Draw the structural formula for 2-pentene.

G) Draw the dot diagram for a 2-pentene molecule.

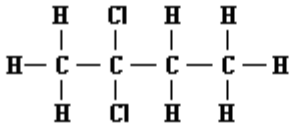
2) Substituted Hydrocarbons Homework

A) Name the following compounds

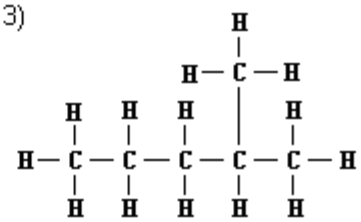
1)



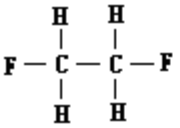
2)



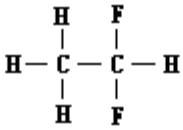
3)



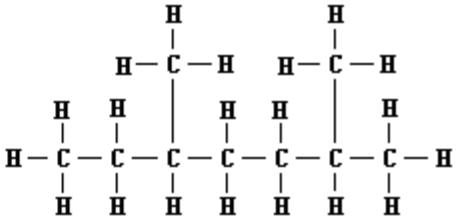
4)



5)



6)



B) Draw the following compounds:

1) 2 chloro propane

2) 1,2 dichloro butane

3) 1,4 dichloro pentane

4) 3 methyl heptane

5) 2,2 dimethyl octane

C) Multiple-Choice and Short-Answer

_____1) Which of the following reactions is an addition reaction?

a) $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$
b) $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$
c) $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$
d) $C_3H_8 + HBr \rightarrow C_3H_7Br + H_2$

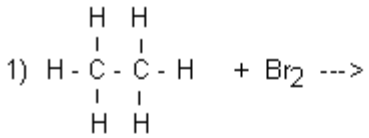
_____2) Which of the following hydrocarbons can undergo an addition reaction?

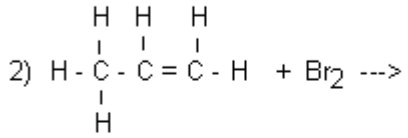
a) C_3H_8 b) C_4H_8 c) C_5H_{12} d) CH_4

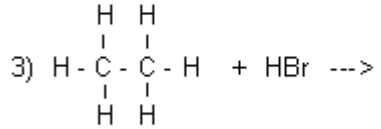
_____3) Which of the following products can form when propane reacts with diatomic chlorine (Cl_2)?

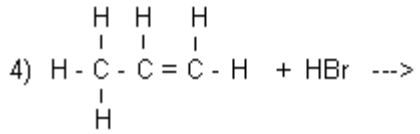
a) $C_3H_8Cl_2$ b) C_3H_7Cl c) $C_3H_7Cl_2$ d) C_3H_8Cl

D) Complete the following reactions and indicate whether they are addition or substitution reactions. Name the halocarbon formed from the reaction.









E) State what kind of reaction can form the following products and identify the reactants that are needed to make those products.

1) 1 fluoro butane

Type of Reaction:_____

Reactants Needed:_____

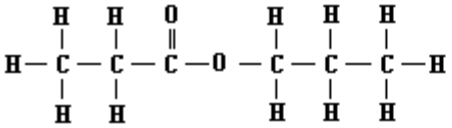
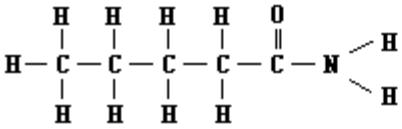
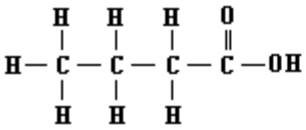
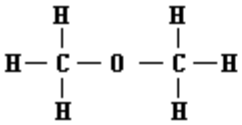
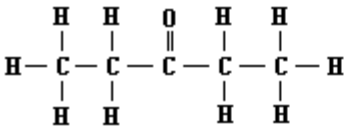
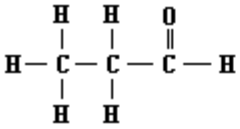
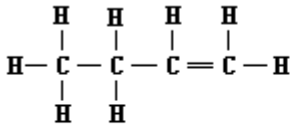
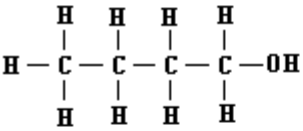
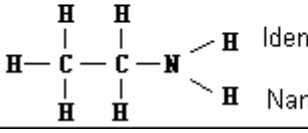
2) 1,2 dichloro butane

Type of Reaction:_____

Reactants Needed:_____

3) Of Functional Groups and Families Homework

A) Complete the following table:

	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:
	Identify Family: Name:

B) Draw the structures of the following organic compounds.

Name	Family	Structural Formula
2-pentanone		
Propanoic acid		
Ethanamine		
Butanamide		
Methyl ethanoate		
Methyl propyl ether		
2- pentanol		
1-pentanol		

_____C) Which of the following molecules is an isomer of propanol?

a) propanone b) methyl ethyl ether c) propanal d) propanoic acid

D) Draw the structural formula of the alcohol that is an isomer of ethyl propyl ether:

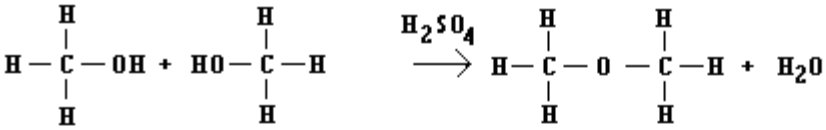
_____E) Which of the following alcohols has the largest number of possible isomers?

a) methanol b) ethanol c) propanol d) butanol

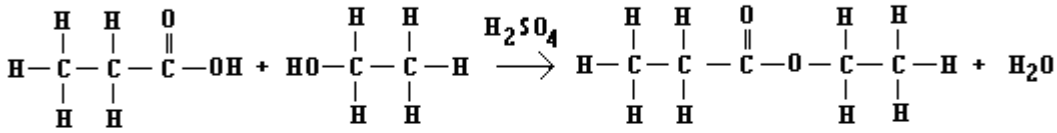
Explain:_____

4) Organic Reactions Homework

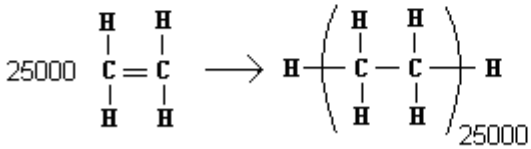
A) Identify the type of reaction taking place and *name each of the reactants and products.*



Reaction Type:_____



Reaction Type:_____



Reaction Type:_____

B) Identify the type of reaction by writing it in the specified box. Each type of reaction occurs only once.

Reaction	Type	How Do You Know?
$C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$		
$CH_3OH + CH_3COOH \rightarrow CH_3COOCH_3 + H_2O$		
$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$		
$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$		
$C_3H_8 + HBr \rightarrow C_3H_7Br + H_2$		
$CH_3OH + CH_3OH \rightarrow CH_3OCH_3 + H_2O$		
$1200\ C_2H_4 \rightarrow -(-C_2H_4-)-_{1200}$		

C) Name the reaction type and reactants needed to form the following organic compounds:

1) propyl butanoate

Type of Reaction:_____

Reactants Needed:_____

2) methyl propyl ether

Type of Reaction:_____

Reactants Needed:_____

3) polypropylene

Type of Reaction:_____

Reactants Needed:_____

D) Write the dehydration synthesis between 1-propanol and butanoic acid by drawing the structural formulas of the reactants and products. Name the product formed by this reaction.

E) Multiple Choice Questions: Place your answer in the space in front of each question.

_____1) The reaction that occurs when a hydrocarbon is heated in the presence of oxygen is called
a) combustion b) fermentation c) saponification d) vulcanization

_____2) The cross-linking of rubber molecules with sulfur to toughen it is called
a) combustion b) fermentation c) saponification d) vulcanization

_____3) The reaction that is used to manufacture soap is called
a) combustion b) fermentation c) saponification d) vulcanization

_____4) The reaction that produces ethanol by the digestion of sugars by yeast is called
a) combustion b) fermentation c) saponification d) vulcanization

_____5) Which reaction can be used to make 2,3 dichloro pentane?
a) addition b) substitution c) etherification d) esterification

_____6) Which reaction can be used to make propyl ethanoate?
a) addition b) substitution c) etherification d) esterification

_____7) What is a by-product of saponification?
a) ethanoic acid b) propanone d) ethylene glycol d) glycerol