Ms. Randall
Regents Chemistry
Unit 12: Organic Chemistry Unit Notes

Unit Objectives: *Upon completion of the unit students should be able to:*

1. Classify an organic compound based on its structural or condensed structural formula.
2. Draw a structural formula with the functional group(s) on a straight chain hydrocarbon backbone, when given the IUPAC name for the compound.
3. Draw structural formulas for alkanes, alkenes, and alkynes containing a maximum of ten carbon atoms.
4. Define hydrocarbons as compounds that contain only carbon and hydrogen.
5. Compare saturated hydrocarbons and unsaturated hydrocarbons.
6. Differentiate between Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids.
7. Recognize functional groups and how they impart distinctive physical and chemical properties to organic compounds.
8. Define isomers of organic compounds have the same molecular formula, but different structures and properties.
9. Recognize and write organic reactions including addition, substitution, polymerization, esterification, fermentation, saponification, and combustion.

Vocabulary:

- **Addition reaction**
- **Alcohol**
- **Alkane**
- **Alkene**
- **Alkyl group**
- **Alkyne**
- **Allotrope**
- **Amide**
- **Amine**
- **Combustion Dehydration**
- **Synthesis**
- **Ester**
- **Esterification**
- **Ether**
- **Fermentation**
- **Halocarbon**
- **Hydrocarbon**
- **Isomer**
- **Ketone**
- **Monomer**
- **Organic acid**
- **Polymer**
- **Polymerization**
- **Saponification**
- **Saturated hydrocarbon**
- **Substitution**
- **Unsaturated Hydrocarbon**

Lesson 1: What is an Organic Compound?

Objective:
- ***Differentiate between an organic compound and an inorganic compound***
- ***Explain why organic properties make them insoluble in water and have relatively low BP***
- ***Differentiate between saturated and unsaturated hydrocarbons***
- ***Determine the name of alkanes, alkenes and alkynes using Table P and Q***

Although originally defined as the chemistry of biological molecules, organic chemistry has since been redefined to refer specifically to carbon compounds — even those with non-biological origin. Some carbon molecules are not considered organic, with carbon dioxide being the most well known and most common inorganic carbon compound, but such molecules are the exception and not the rule. Major sources of organic compounds are: petroleum, coal, wood, plants, & animals.

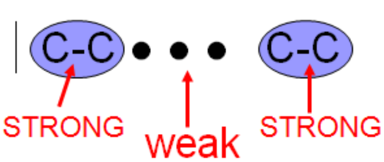
Organic chemistry focuses on carbon and following movement of the electrons in carbon chains and rings, and also how electrons are shared with other carbon atoms and other atoms. Organic chemistry is primarily concerned with the properties of covalent bonds and non-metallic elements, though ions and metals do play critical roles in some reactions.

The applications of organic chemistry are myriad, and include all sorts of plastics, dyes, flavorings, scents, detergents, explosives, fuels and many, many other products. Read the ingredient list for almost any kind of food that you eat — or even your shampoo bottle — and you will see the handiwork of organic chemists listed there.

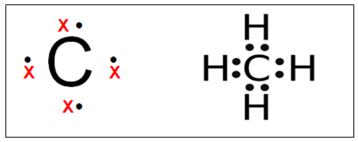
Unsaturated organic compounds contain at least one double or triple covalent bond. In a double covalent bond, two pairs of electrons are shared between two atoms; in a triple bond, three pairs are shared. Isomers are molecules that have the same molecular formula, but different structural formulas and different physical and chemical properties as a result**.** **Hydrocarbons tend to be nonpolar molecules**. **Vander Waals forces** are the weak attractive forces between nonpolar molecules. The attraction increases with increasing molecular mass, resulting in higher melting/boiling points**.** Since Hydrocarbons are nonpolar they tend to be insoluble in water, but soluble in other nonpolar solvents like lamp oil (hexane).

Because **they are Nonelectrolytes, they are POOR Conductors of Electricity**. They **DO NOT dissociate** to form ions in solution. They are **molecules (covalent compounds).**

They have **LOW melting points – due to their weak intermolecular forces. The melting point generally increases with an increase in the number of carbons.** They are Combustible (flammable), which is why we use them for energy.

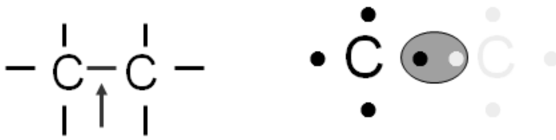


Recall: Carbon forms 4 COVALENT BONDS which may be single, double or triple



Types of bonds

<u>Single Bond</u> – single covalent bond in which they share **1** pair of electrons. (2 e-)



<u>Double Bond</u> – carbon atoms may share **2** pairs of electrons to form a double bond.

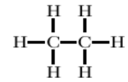
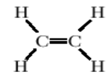
<u>Triple Bond</u> – carbon atoms may share **3** pairs of electrons to form a triple bond

Because carbon can bond to itself, it makes it possible for there to exist a large number of organic molecules, even more numerous than inorganic compounds.

<u>Hydrocarbons</u>

Hydrocarbons are Organic compounds that **<u>ONLY</u>** contain **CARBON** and **HYDROGEN**
The homologous series defines the three types of hydrocarbons that can exist. They are a group of organic compounds with similar properties and structures. TABLE Q gives the general formula and examples (name and structure).

Table Q
Homologous Series of Hydrocarbons

Name	General Formula	Examples	
		Name	Structural Formula
alkanes	C_nH_{2n+2}	ethane	
alkenes	C_nH_{2n}	ethene	
alkynes	C_nH_{2n-2}	ethyne	$H-C\equiv C-H$

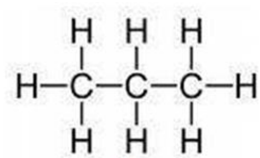
n = number of carbon atoms

Hydrocarbons are defined by the types of bonds that exist between the carbon atoms in the molecule.

Saturated hydrocarbons contain **SINGLE bonds** ONLY!! They contain the maximum # of hydrogen possible (saturated).

Alkanes are a Group of SATURATED hydrocarbons with the general formula: $\mathbf{C_nH_{2n+2}}$. They are used as burning FUELS

Example:



Example: propane

Naming Alkanes

- Count up the # of carbons
- Use TABLE P to determine the prefix
- Name ends in -**ANE**

Table P
Organic Prefixes

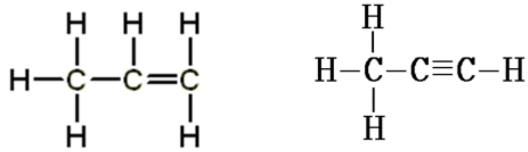
Prefix	Number of Carbon Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Example: C_5H_7

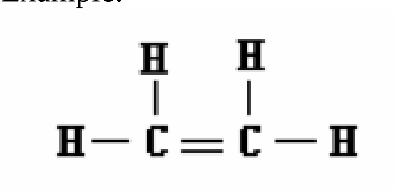
- 5 carbons (5 = pent)
- All single Bonds (ANE)
  $C_5H_{2(5)+2}$
- Name: PENTANE

Unsaturated hydrocarbons contain multiple bonds. They have at least **1 double** or **triple** bond between carbons (not saturated with hydrogens)

Examples:



Alkenes are a group of UNSATURATED hydrocarbons with the general formula: $C_nH_{2n.}$
They contain 1 Double Bond and always twice as many hydrogens as carbons in formula
Example:

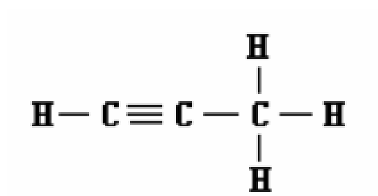


Naming Alkenes
Naming alkenes is the same as naming alkanes except the ending is –ENE.

Example C_5H_{10}

- 5 carbons (5 = pent)
- Contains Double Bond (ENE)
  $C_5H_{2(5)}$
- Name: PENTENE

Alkynes are a group of UNSATURATED hydrocarbons with the general formula: C_nH_{2n-2}
They contain 1 TRIPLE BOND.



Naming Alkynes
Naming alkenes is the same as naming alkanes except the ending is –YNE.

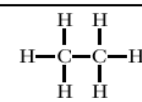
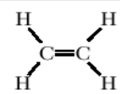
Example C_5H_8

- 5 carbons (5 = pent)
- Contains TRIPLE Bond (YNE)
  $C_5H_{2(5)-2}$
- Name: PENTYNE

How to determine the type of hydrocarbon using Table Q:

1. Count up the number of carbons
2. If the # of Hydrogen are **double** the **# of carbons** it's an **alkene**
3. If **more than double** its an **alkane**, **less than double** it's an **alkyne**
   Example: C_5H_{12} (12 is more than double 5 so it's an alkane)

Table Q
Homologous Series of Hydrocarbons

Name	General Formula	Examples	
		Name	Structural Formula
alkanes	C_nH_{2n+2}	ethane	
alkenes	C_nH_{2n}	ethene	
alkynes	C_nH_{2n-2}	ethyne	H—C≡C—H

n = number of carbon atoms

Lesson 2: Structural formulas

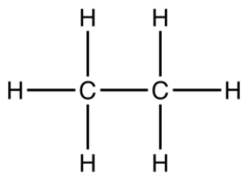
Objective:

- ***Differentiate between the structural formulas of alkanes, alkenes and alkynes***
- ***Construct structural formulas of alkanes, alkenes, and alkynes***

***Watch this:* Click here this video IS the lesson!!!!! The notes are a short summary.**

There are three different ways we can represent organic molecules.

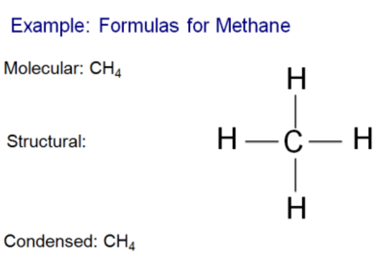
1. **MOLECULAR FORMULA**-shows the # OF ATOMS of each ELEMENT in a compound; least informative formula.
   Example: C_2H_6

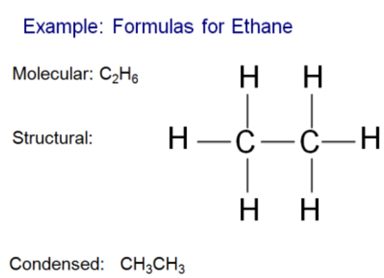
2. **STRUCTURAL FORMULA-** diagram of the molecular structure of compound
   Example: 

3. **CONDENSED STRUCTURAL FORMULA-** each carbon is written separately followed by atoms bonded to it.
   Example: CH_3CH_3

Drawing structural formulas of Alkanes

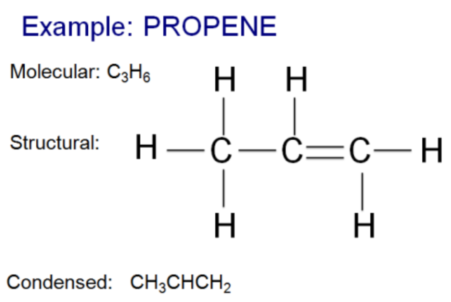
- Use TABLE P and TABLE Q to determine # of CARBON and HYDROGEN
- Remember each Carbon must have FOUR bonds

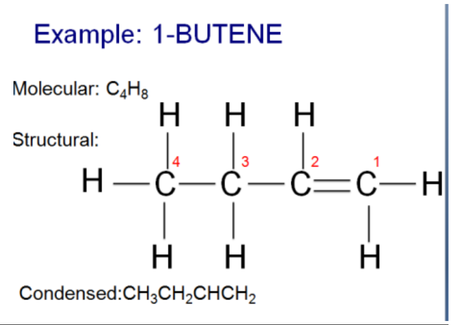




Drawing structural formulas of Alkenes

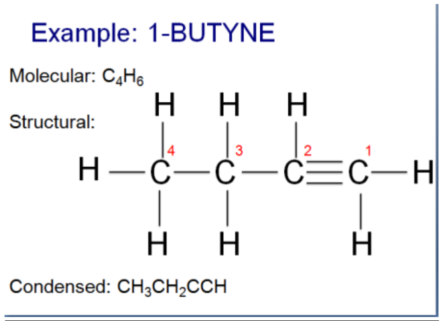
- Same as Alkanes except….
  - If there are more than 3 carbons you need to give the location of DOUBLE BOND
  - Always START numbering the carbons at the end CLOSEST to the double bond to give the bond the lowest number





Drawing structural formulas of Alkynes

- Same as alkenes except you add a TRIPLE BOND

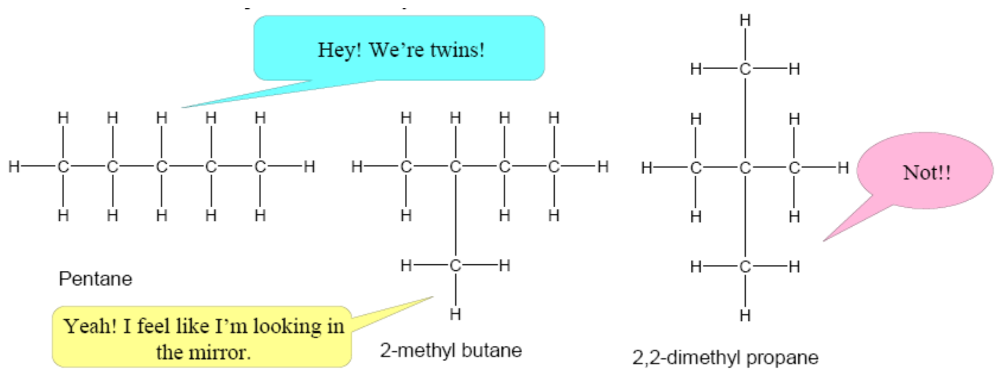


Lesson 3: Branched alkanes

Objective:

- ***Determine the name of branched alkanes***

Watch this: **[Click here](#) this video IS the lesson!!!!! The notes are a short summary.**



ALKYL GROUPS are carbon chain branches sticking off the main parent chain of hydrocarbons. This is how isomers are usually seen.

Naming Alkyl groups

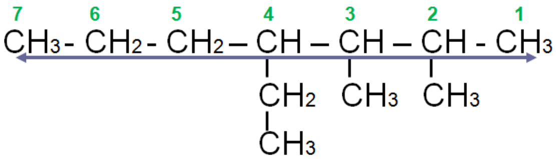
- Count # of carbons in alkyl group (branch)
- Use prefix (TABLE P)
- Add Suffix "yl" to prefix

Ex. $–CH_3$ (Methyl)

Table P
Organic Prefixes

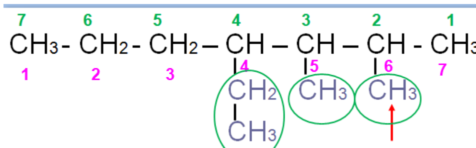
Prefix	Number of Carbon Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Follow the steps:



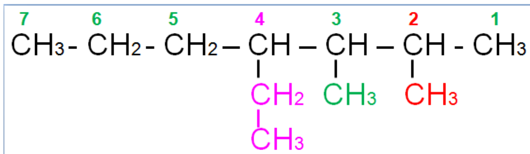
Step 1: Find the longest continuous chain of carbons (parent chain)

There are 7 continuous carbons, so the parent chain is heptane.



Step 2: Number the carbons in parent chain starting with the end that will give the attached groups the smallest #.

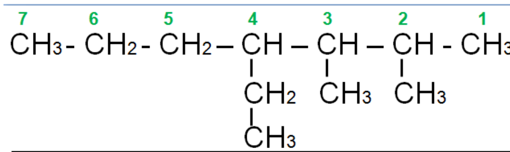
The chain is numbered from right to left because it gives the attached groups the lowest possible number



Step 3 : Add numbers to the names of the groups to identify their positions on the chain.

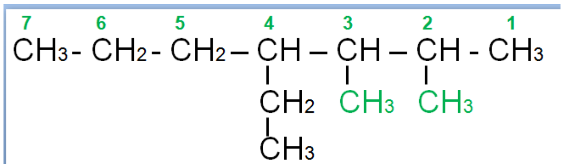
In this ex. the positions are:

2- methyl, 3- methyl, 4- ethyl



Step 4: Use prefixes if a group appears more than once in the structure.

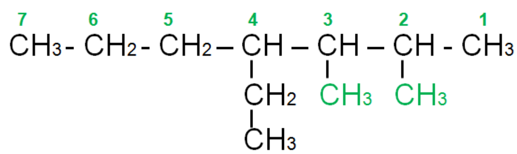
Di	=	twice
Tri	=	three times
Tetra	=	four times
Penta	=	five times



This ex. has 2 methyl groups so dimethyl is used.

Step 5: List the alkyl groups in alphabetical order.

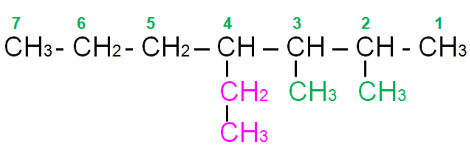
In this ex. dimethyl is listed before the ethyl.



Step 6: Use punctuation

- use commas to separate numbers

-use hyphens to separate numbers with words.



- The name of this compound is:

2,3-dimethyl – 4-ethyl heptane

Lesson 4: Isomers

Objective:

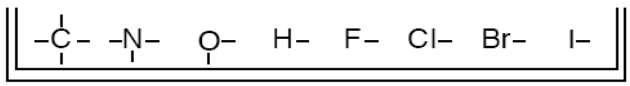
- ***Identify and construct isomers of alkanes, alkenes and alkynes***

***Watch this:* Click here this video IS the lesson!!!!! The notes are a short summary.**

Isomers are compounds with **the SAME MOLECULAR formula but different STRUCTURAL FORMULA**. They **have different properties because of the difference in structure**. The more carbons there are in the molecule then the more possible isomers that can exist.

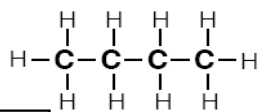
1. Isomers of Alkanes are known as branched alkanes(previous lesson)

The building blocks:

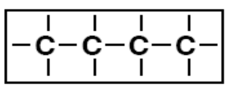


Define "isomer":

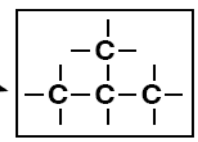
example C_4H_{10}



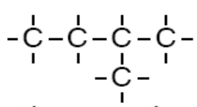
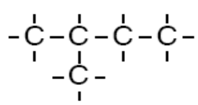
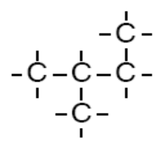
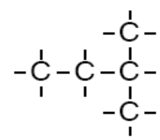
(w/o the H's):



and C_4H_{10}



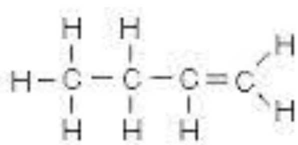
Caution!: Molecules are constantantly being bent, twisted and flipped as they collide with one another, but this does not change their bonding arrangements. Thus, bending, twisting and flipping of a structural formula does not give rise to new isomers.

so  and  and  and 

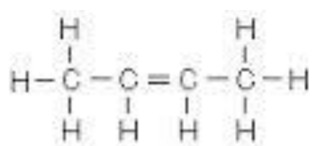
are not isomers, they are all repeats of the same structure.

2. Isomers of alkenes and alkynes just have the double or triple bond in a different location.

Example: Two isomers of Butene C_4H_8



1- butene



2-butene

Lesson 5: Functional groups

Objective:

- ***Determine the name of the organic compound based upon the functional groups***

Table R
Organic Functional Groups

Class of Compound	Functional Group	General Formula	Example
halide (halocarbon)	—F (fluoro-) —Cl (chloro-) —Br (bromo-) —I (iodo-)	*R*—*X* (*X* represents any halogen)	$CH_3CHClCH_3$ 2-chloropropane
alcohol	—OH	*R*—OH	$CH_3CH_2CH_2OH$ 1-propanol
ether	—O—	*R*—O—*R'*	$CH_3OCH_2CH_3$ methyl ethyl ether
aldehyde	—C(=O)—H	*R*—C(=O)—H	$CH_3CH_2C(=O)$—H propanal
ketone	—C(=O)—	*R*—C(=O)—*R'*	$CH_3C(=O)CH_2CH_2CH_3$ 2-pentanone
organic acid	—C(=O)—OH	*R*—C(=O)—OH	$CH_3CH_2C(=O)$—OH propanoic acid
ester	—C(=O)—O—	*R*—C(=O)—O—*R'*	$CH_3CH_2C(=O)OCH_3$ methyl propanoate
amine	—N(—)—	*R*—N(*R'*)—*R''*	$CH_3CH_2CH_2NH_2$ 1-propanamine
amide	—C(=O)—NH	*R*—C(=O)—NH(*R'*)	$CH_3CH_2C(=O)$—NH_2 propanamide

R represents a bonded atom or group of atoms.

Halides and Table R

Halocarbons are typically classified in the same ways as the similarly structured organic compounds that have hydrogen atoms occupying the molecular sites of the halogen atoms in halocarbons. Common uses for halocarbons have been as solvents, pesticides, refrigerants, fire-resistant oils, ingredients of elastomers, adhesives and sealants, electrically insulating coatings, plasticizers, and plastics. Many halocarbons have specialized uses in industry. One halocarbon, sucralose, is a sweetener.

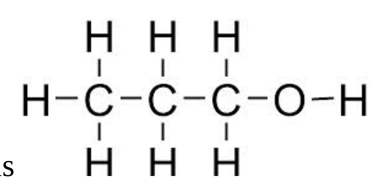
Examples of chlorocarbons are carbon tetrachloride and tetrachloroethylene; the best known fluorocarbon is the resin polytetrafluoroethylene, called Teflon. **Halocarbons have a halogen attached to the carbon chain.**

Alcohols and Table R

Alcohols are often used in science labs as a solvent to make solutions. As we will see later, they are also needed to make esters. Mouthwash, hairspray, rubbing alcohol (antiseptic) and alcoholic beverages all contain alcohol.

The functional group for a molecule categorized as an alcohol is –OH.

The structural formula of 1 – propanol is



(Notice at the bottom of Table R it says that R stands for "a bonded atom or group of atoms". Another way to say this is that "R" stands for the "rest" of the C's and H's.)

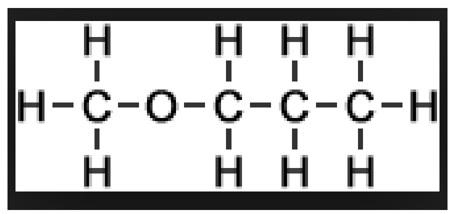
Ethers and Table R

Ethers are used as anesthetics during surgery. They are also used as a starter fluid for diesel engines.

The general formula for a molecule categorized as ether is R-O-R'. Notice at the bottom of Table R it says that R stands for "a bonded atom or group of atoms". Another way to say this is that "R" stands for the "rest" of the C's and H's.

The functional group is the "O" in the middle of two carbon-hydrogen chains

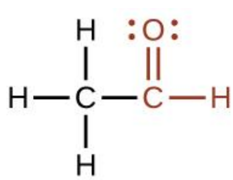
Ether has the condensed formula of $CH_3CH_2CH_2OCH_3$. Its structural formula is



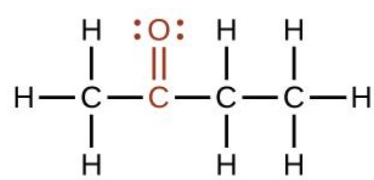
Aldehydes & Ketones and Table R

Aldehydes are often used as flavorings in foods and beverages; specifically vanilla essence.
Ketones are used as solvents and have a strong odor. Nail polish remover is the ketone named acetone (propanone).

The functional group for aldehydes and ketones is the same, though its location along a chain of carbons is not. The functional group for both is a carbon double bonded to oxygen. It is located on the end carbon in an aldehyde and in the middle of the chain with a ketone.



CH_3CHO
An aldehyde
ethanal (acetaldehyde)



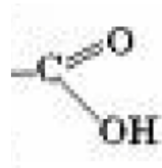
$CH_3COCH_2CH_3$
A ketone
butanone

Organic Acids and Table R

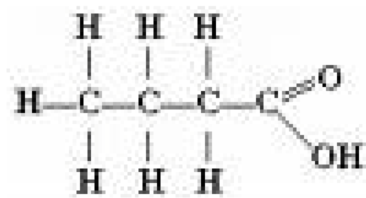
Organic acids are primarily derived from plants and animals and are used to make esters, soaps, and waxes. They are also used in food preservation because they control against bacteria, as well as when contact is needed with a metal for a long period of time because they are less reactive than other acids like HCl. Vinegar, also known as acetic acid, is an organic acid, as are lactic acid and citric acid.

The functional group for an organic acid is the COOH on the end. It is a carbon with both a double bonded oxygen and an –OH group.

You know that acids are acids BECAUSE they produce H^{1+} ions when dissolved in water. So when an organic acid dissolves in water, what part of the functional group falls off?



When an organic acid dissolves in water, the resulting pH of the solution would be <7



Organic acids are the substances that cause many fruits and veggies to have sour tastes. The most common one is vinegar (made from grapes or apples). Its IUPAC name is "ethanoic acid."

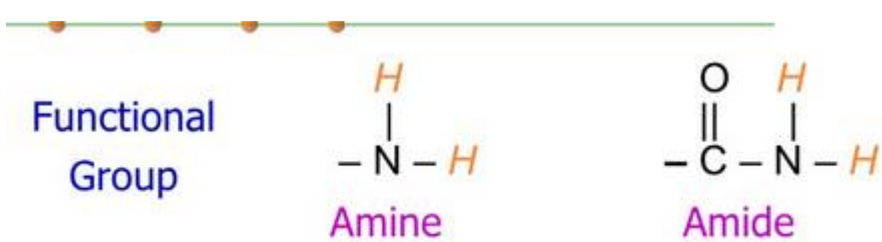
The alternate acid/base theory says that acids are "proton donors." An H atom without its electron is an H^{1+} ion, so explain how this theory is NOT in conflict with our previous idea of acids.

<u>Amines & Amides and Table R</u>

Amines are used as industrial solvents and many have a fishy odor. They make up part of the essential amino acids that our bodies need and can also be used as dyes or in pharmaceuticals. There is research being done to see how they might be used to decrease CO_2 and other greenhouse gases. Amides also contribute to the amino acids in our body and are often made into polymers (more on this later.)

As described previously, an acid can be considered a "proton donor." Conversely, a base can be a "proton acceptor." In other words, our understanding of what a base is can be expanded to include substances that have features that might attract an H^{1+} ion. Amines are often used as bases in organic reactions because they are not quite as "harsh" as Arrhenius bases like NaOH.

Amides are derived from carboxylic acids. A carboxylic acid contains the -COOH group, and in an amide the -OH part of that group is replaced by an $-NH_2$ group. So . . . amides contain the $-CONH_2$ group. The melting points of the amides are high for the size of the molecules because they can form hydrogen bonds. The hydrogen atoms in the $-NH_2$ group are sufficiently positive to form a hydrogen bond with a lone pair on the oxygen atom of another molecule.
The small amides are soluble in water because they have the ability to hydrogen bond with the water molecules.



Lesson 6: Organic Reactions

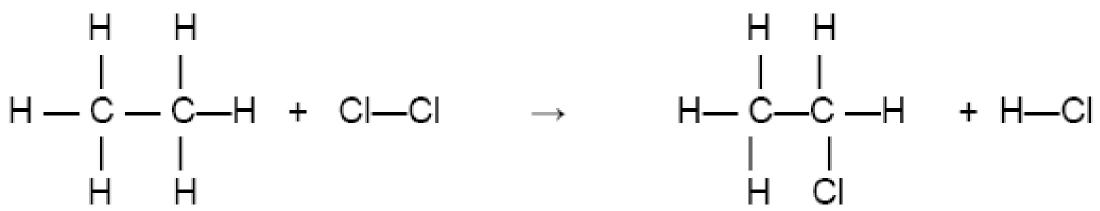
Objective:

- ***Differentiate between the types of organic reactions***
- ***Compose addition and substitution reactions***

Many organic reactions lead to products we use every day. Organic reactions can be categorized by looking at the reactants used and the products formed. Soap, alcohol, fragrances, flavors, and flames in your gas barbeque are all products of organic reactions.

A. Substitution reaction   general formula:

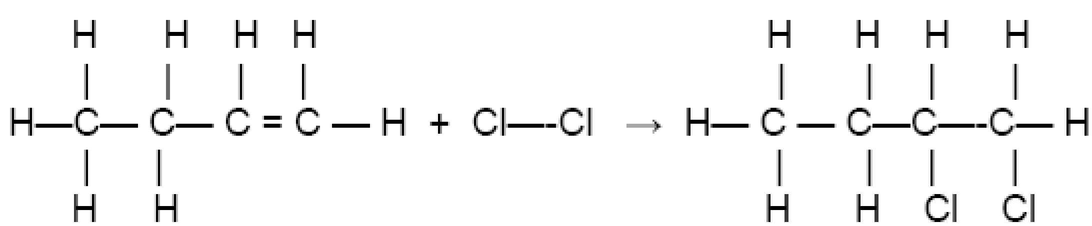
Alkane + Diatomic yields Halocarbon + acid



ethane + chlorine → chloroethane hydrogen chloride

B. Addition Reaction general formula:

Alkene/Alkyne   + Diatomic yields Halocarbon



1- butene + chlorine → 1,2 - dichlorobutane

C. Combustion Reaction general formula:

Hydrocarbon + oxygen yields Carbon dioxide + water

This is just a fancy word for "**burning**." Burning requires a fuel and O_2 from the air. Organic compounds that burn cleanly (do not produce poisonous gases or a lot of carbon soot) are:

Alkanes, Alkenes, Alkynes, Alcohols

These families represent almost all the important fuels used in modern times:

- Natural gas = methane Gasoline = octane
- Welding Torches use Ethyne (acetylene)
- Bio-fuel = Ethanol mixed with octane at the gas station to make “gas-ahol” (most gas is now blended with up to 10% ethanol).

Reaction Example: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

Products of clean (complete) combustion are **always carbon dioxide and water**. Incomplete combustion (not enough O2 available) results in soot (C) and sometimes poisonous carbon monoxide as well.

Check out the combustion reactions on Table I. Are they exothermic or what??

$$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$$

propane + oxygen → carbon dioxide + water

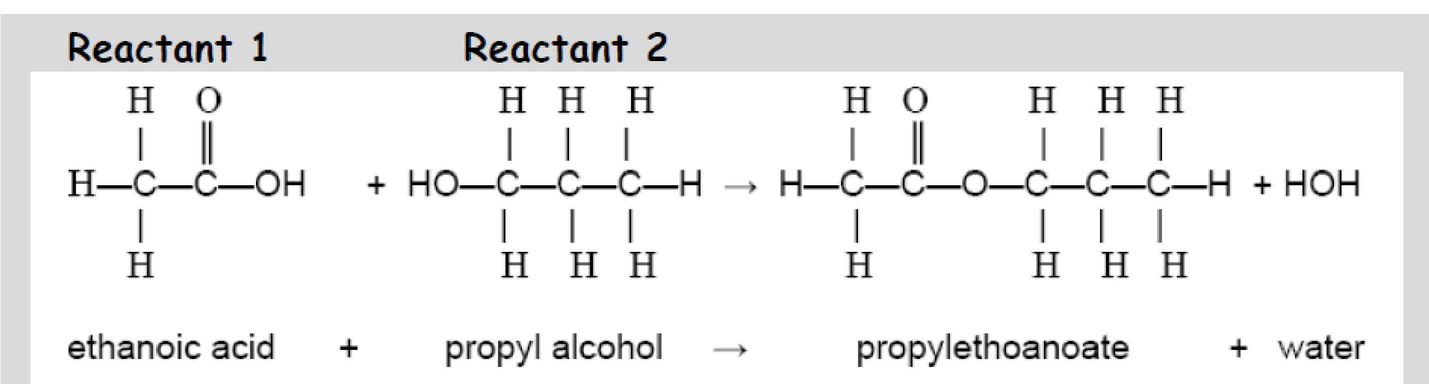
D. Esterification general formula:

Organic acid + alcohol yields ester + water

Esters General Formula: **R-C-O-R’, R-CO_2R’ or R-COOR’**
Esters produce pleasant odors. Many compounds naturally found in fruits can be prepared in the laboratory using an esterification reaction and are then used in candies and perfume.
They are made from an acid and an alcohol with the elimination of water:

R-CO_2H + R’-O-H → R-CO_2R’ + H_2O

Named as a combination of the “parent” alcohol and “parent” carboxylic acid.
For example: CH_3-CO_2H + CH_3-O-H → CH_3-C-O-CH_3 + H_2O
methyl ethanoate



E. Fermentation general formula

Sugar in the presence of an enzyme(catalyst) yields alcohol + carbon dioxide

Fermentation:

Fermentation is easy. It involves the action of an enzyme (biological catalysts) called "zymase" on sugar molecules. Yeast is a fungus that contains zymase. The reaction always produces the alcohol named ethanol (the drinking kind) and CO_2 gas. Sometimes when humans do fermentation they are after the CO_2. When making bread or pizza dough, the reaction acts on the sugar in the dough and is used to "leaven" the dough, or make it "rise" and get fluffy due to the pockets of gas produced in the dough. The alcohol cooks out in the oven in this case. When making beer or wine, the reaction uses a fruit or grain source of sugar. The goal is to keep the alcohol, and the CO_2 gas produced is vented off and the reaction continues until the beverage has "aged" enough to be consumed. When making champagne, both the alcohol and the CO_2 are kept.

$$C_6H_{12}O_6 \xrightarrow{\text{Yeast/zymase}} 2C_2H_5OH + 2CO_2$$

Sugar → ethanol + carbon dioxide

F. Saponification general formula:

Fat+ base(either NaOh or KOH) yields soap + glycerin

Another easy one. This involves the action of the base NaOH on fatty acids (organic acids found in animal "fats" and "greases"). The **product is "SOAP**." Notice that the first four letters of "**Sapo**nification" rearrange to spell "**Soap**." If you work at a fast food restaurant, you may be aware that the grease is collected at the end of each day in big drums out back, and that someone comes by periodically and actually buys the stuff (to make soap silly, they don't eat it).

$$C_3H_5(C_{17}H_{35}COO)_3 + 3NaOH \rightarrow 3\,C_{17}H_{35}COONa + C_3H_5(OH)_3$$

Fat + Strong Base → Soap + Glycerin

**NOTE: SAPOnification looks like SOAP!!

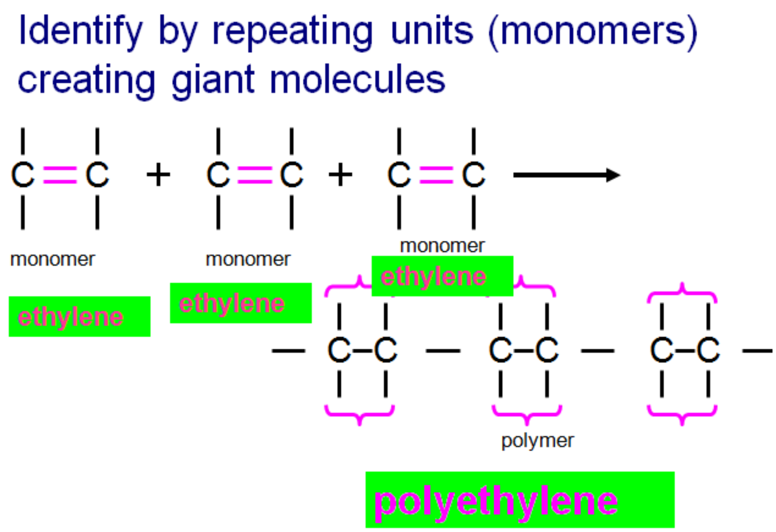
Look for really big molecules on both sides if the yields arrow.

G. Polymerization

Polymers: Large molecules with repeating units (anywhere from 500-20,000 units)

Polymerization is the process in which long-chain molecules (polymers) form as small repeating subunits (monomers) bond together
They can be natural (proteins) or artificial (plastics)

- starch – long chains of sugars
- proteins – long chains of amino acids
- cellulose – made of repeating units of sugar



There are two types you need to know:

Addition Polymerization occurs by adding small alkenes together and breaking the double bond, to create a large chain.
They can be identified by "n" which represents a large number of monomers linked together.

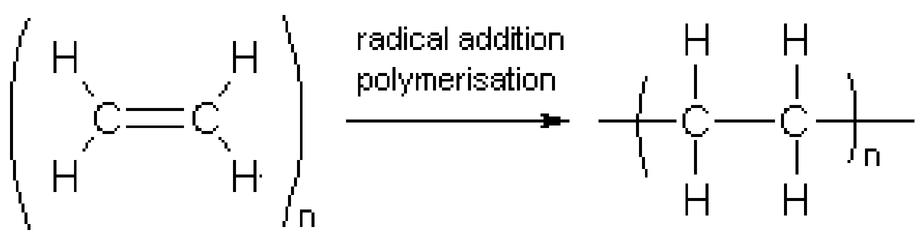
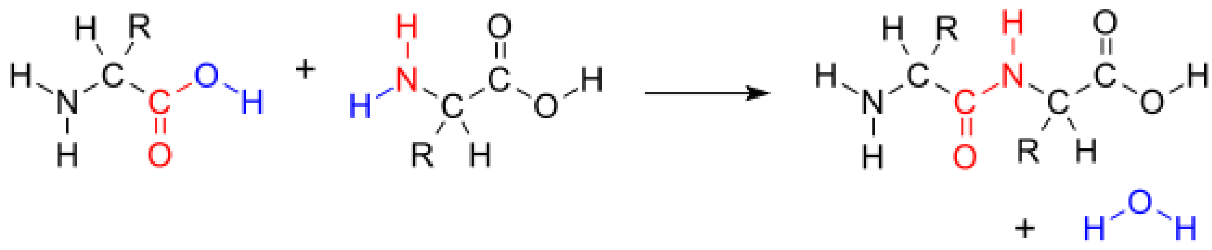
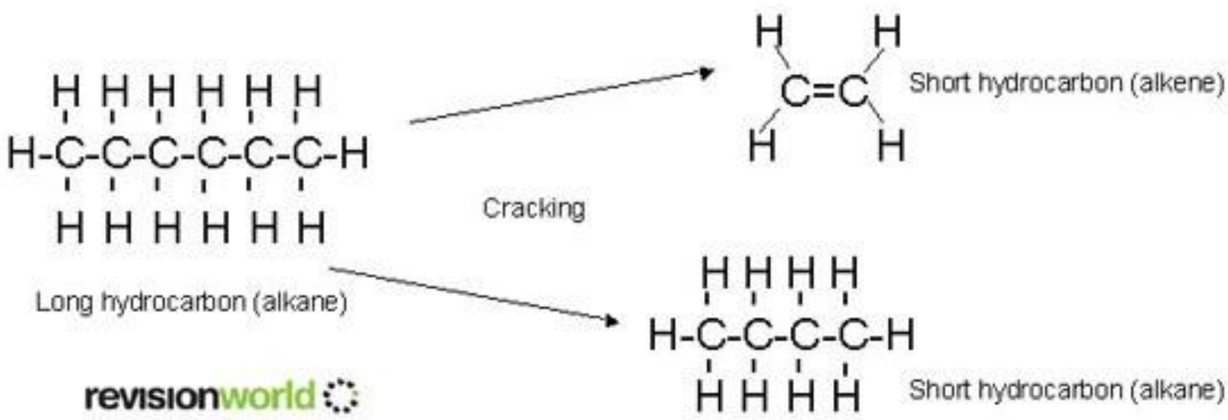


Fig 1: The polymerisation of ethene in to poly(ethene)

<u>Condensation Polymerization occurs</u> when two molecules are joined by the removing water



<u>H. Cracking</u> is a process in which large hydrocarbons are broken into smaller chains by heating them. Fossil fuels are cracked into many components such as octane (gasoline) propane, etc.



<u>One last skill…</u>

Finding the missing reactant or product in organic reactions

In balanced reactions the number of atoms on the left must equal the number of atoms on the right.

Example: $C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + \_\_\_\_\_\_\_\_$

Missing product must be **HCl**
This is a **substitution reaction** because hydrogen atom of ethane is replaced by chlorine.