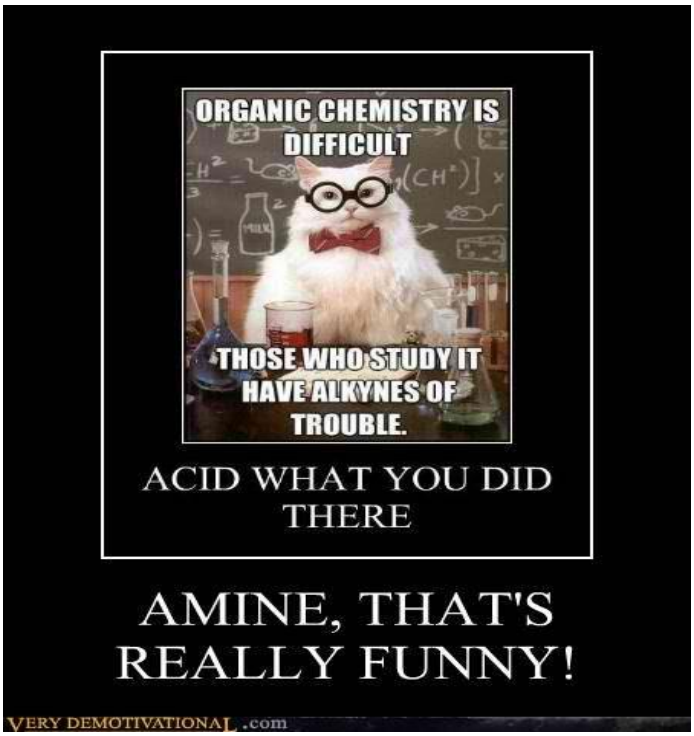
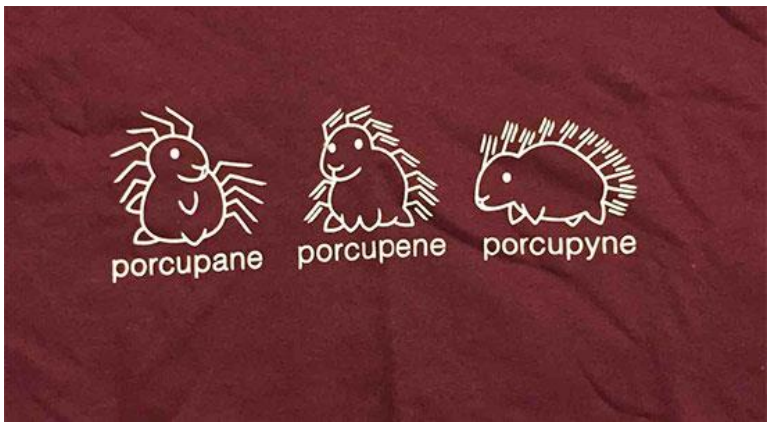
Name:

Regents Chemistry:

Notes: Unit 14 Organic Chemistry





KEY IDEAS

- Organic compounds contain carbon atoms which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC system. (3.1ff)
- Hydrocarbons are compounds that contain only carbon and hydrogen. Saturated hydrocarbons contain only single carbon-carbon bonds. Unsaturated hydrocarbons contain at least one multiple carbon-carbon bond. (3.1gg)
- Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are types of organic compounds that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds. (3.1hh)
- Isomers of organic compounds have the same molecular formula, but different structures and properties. (3.1ii)
- In a multiple covalent bond, more than one pair of electrons are shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond. (5.2e)
- Types of organic reactions include: addition, substitution, polymerization, esterification, fermentation, saponification, and combustion. (3.2c)

3.1eeTypes of chemical formulas include empirical, molecular, and structural.

PROCESS SKILLS

- Classify an organic compound based on its structural or condensed structural formula, i.e., CH3COOH or O (3.1 xvii)
  -C-C-O-H

- Draw a structural formula with the functional group(s) on a straight chain hydrocarbon backbone, when given the IUPAC name for the compound. (3.1xx)
- Draw structural formulas for alkanes, alkenes, and alkynes containing a maximum of ten carbon atoms. (3.1xxi)
- Identify organic reactions. (3.2 iv)

Vocabulary:

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.

Vocabulary:

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.

Lesson 1: Introduction to Organic Chemistry

Objective:

- ***Identify organic compounds.***
- ***Identify the properties of organic compounds***
- ***Use Table P to identify hydrocarbons***
- ***Determine the name of alkanes, alkenes and alkynes using Table P and Q***
- ***Differentiate between saturated and unsaturated hydrocarbons***

ORGANIC CHEMISTRY: The chemistry of _____ compounds

- Major sources of organic compounds are:
  petroleum, coal, wood, plants, & animals

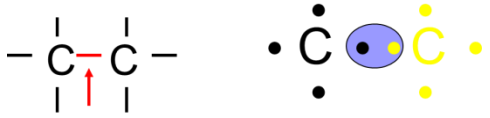
Carbon has _____**valence electrons** therefore it will **bond** _____ **times** to achieve an **octet.**

Dot diagram for Carbon:

Carbon can form large chains or rings – large molecules which are the complex building blocks of life!

TYPES OF BONDS

The total of 4 bonds can include _____, _____, or _____ bonds:



_____ = ____ electrons or ____ electron pairs

_____ = _____ electrons or ____ electron pairs

_____ = ____ electrons or _____ electron pairs

Properties of organic compounds: *(think oil or wax…)*

Carbon – Carbon bonds, have an electronegativity difference of _____.
Carbon – Hydrogen bonds, have an electronegativity difference of _____.

SO…_____polarity or _____.

1) _____ in water
2) _____ in nonpolar solvents (like dissolves like)

3) covalent bonding, so poor conductors of electricity (_____)

4) weak InterMolecular Forces (IMF) so _____ melting point.

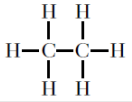
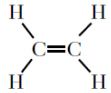
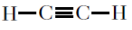
5) Combustible (flammable)

Hydrocarbons: Organic compounds that **ONLY** contain _____ and _____.

Homologous Series of Hydrocarbons:

- Group of organic compounds with similar _____ and _____
- 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	

Note: n = number of carbon atoms

How to determine the type of hydrocarbon from a molecular formula using Table Q

1. Count up the number of carbons
2. If the # of Hydrogen are double the # of carbons it's an alkene (C_nH_{2n})
3. If more than double its an alkane (C_nH_{2n+2}) , less than double its an alkyne (C_nH_{2n-2})

Examples: C_5H_{12}

12>2x5 _____ n=5, so $2n+2 = 12$

C_4H_8

8 = 2x4, so _____ n=4, so $2n = 8$

C_2H_2

2<2x2 so _____ n=2, so $2n-2 = 2$

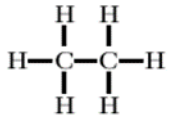
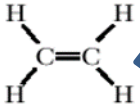
Determining the type of Hydrocarbon using a structural formula:

Match type of bonds. All single = _____ (all C's with four bonds)

one double = _____

one triple = _____

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	

n = number of carbon atoms

NAMING HYDROCARBONS

STEP 1: Make sure it IS a Hydrocarbon (only contains _____ and _____).

STEP 2: Determine the number of _____; then STEP 3: use Table P to find the prefix:

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

EXAMPLES: Find the prefix from Table P

1. C_2H_6 _____
2. C_3H_6 _____
3. C_4H_6 _____
4. C_5H_{12} _____
5. C_6H_{12} _____
6. C_7H_{14} _____
7. C_8H_{18} _____
8. C_9H_{16} _____
9. $C_{10}H_{20}$ _____

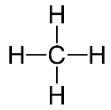
Use the formula (like before) to determine if alk*ane*, alk*ene*, or alk*yne* – that is your SUFFIX.

Example: C_3H_8

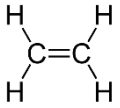
Three Cs so "prop" 8>3x2 so "ane" = PROPANE

Putting Tables P and Q Together

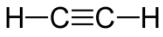
Prefix from Table P; Suffix from Table Q



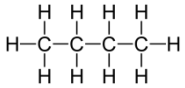
_____ _____



_____ _____



_____ _____



_____ _____

Try These (Prefix from Table P; Suffix from Table Q):

1. C_2H_6 _____ _____
2. C_5H_{12} _____ _____
3. C_3H_6 _____ _____
4. C_4H_6 _____ _____

Saturation:

- Hydrocarbons which are FULL or have the MOST hydrogens -- this requires single bonds. **Alkanes are _____ with single bonds.**
- Hydrocarbons that are unsaturated have double and triple bonds, therefore, they have fewer hydrogen atoms. **Alkenes and alkynes are _____.**

Lesson 2: Structural and Condensed Structural Formulas

Objective:

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

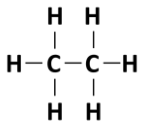
TYPES OF FORMULAS:

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

Ex. **C_2H_6**

2. **STRUCTURAL FORMULA**:
   Diagram of the molecular structure of compound

Ex.



3. **CONDENSED STRUCTURAL FORMULA:**
   Each carbon is written separately followed by atoms bonded to it.

Ex. **CH_3CH_3**

DRAWING STRUCTURAL FORMULAS OF ALKANES

- Use TABLE P and TABLE Q to determine # of CARBON and HYDROGEN
- Connect the Carbons in a chain; then add the hydrogens so that all Carbons are full (saturated)
- Remember each Carbon must have FOUR bonds (ALL SINGLE BONDS)

EXAMPLE: Formulas for Methane
Molecular: CH_4

Structural:

Condensed Structural:

Formulas for Ethane:
Molecular: C_2H_6

Structural:

Condensed Structural:

CHECK YOUR UNDERSTANDING:

Structural Formula for Propane (C_3H_8):

DRAWING STRUCTURAL FORMULAS FOR ALKENES

- Same as Alkanes except….Use a Double Bond (eliminates 2 hydrogens)
- Remember each Carbon must have _____ bonds

EXAMPLE: Draw the formulas for Ethene (need at least 2 Carbons….why?)
Molecular: C_2H_4

Structural:

Condensed Structural:

EXAMPLE: Draw the formulas for Propene
Molecular: C_3H_6

Structural:

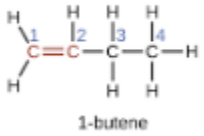
Condensed Structural:

- 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

EXAMPLE: Draw the formulas for 1-Butene
Molecular: C_4H_8

Structural:



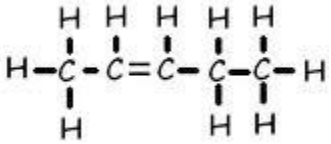
Condensed: $CH_2CHCH_2CH_3$

EXAMPLE: Draw the formulas for 2-butene
Molecular: C_4H_8

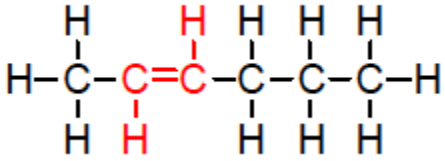
Structural:

Condensed:

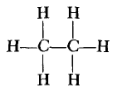
Check your Understanding:
Name this compound:

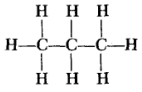


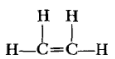
Why is this 2-hexene and not 3-hexene?

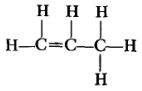


Which compound is propene?

(1) 

(3) 

(2) 

(4) 

DRAWING STRUCTURAL FORMULAS FOR ALKYNES

- Same as alkenes except you add a TRIPLE BOND (and two more hydrogens are removed!).
- Remember each Carbon must have _____ bonds

EXAMPLE: Draw the formulas for 1-Butyne
Molecular: C_4H_6

Structural:

Condensed:

EXAMPLE: Draw the formulas for 2-Butyne

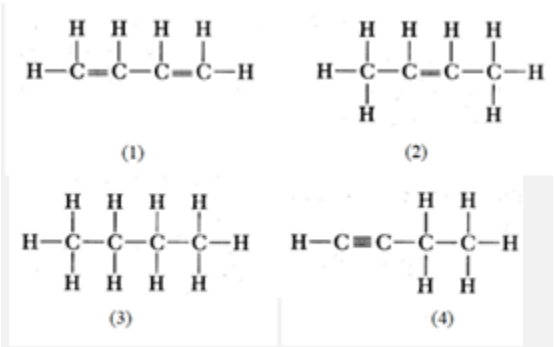
Molecular: C_4H_6

Structural:

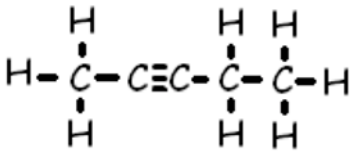
Condensed:

Check your Understanding:

What is the structural formula for 1-butyne?



Name the following (don't forget the location of the double bond):



Lesson 3: Branched Hydrocarbons

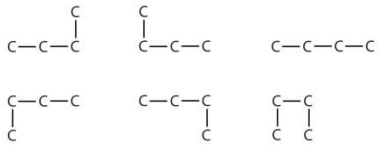
Objective:

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

BRANCHED HYDROCARBONS

Naming Branched Alkanes:
When naming branched alkanes, name the longest chain of CARBONS and use that as the 'last name.' Then name the shorter chains ALKYL GROUP, specifying the position of each branch. Also make sure that your branches are numbered as low as possible.

Locating the Parent Chain: (Be careful, the parent chain must be continuous but does not have to be a straight line. Ex. These are all the butane



NAMING ALKYL GROUPS: (the side groups – not on the longest chain)

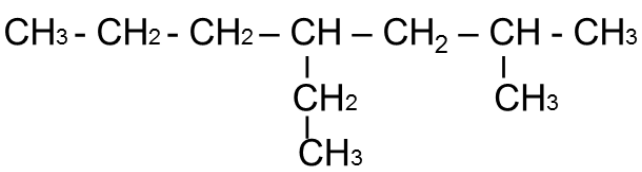
- Count # of carbons in alkyl group (branch)
- Use prefix (TABLE P)
- Add Suffix "**yl**" to prefix

Ex. $-CH_3$ (Methyl)

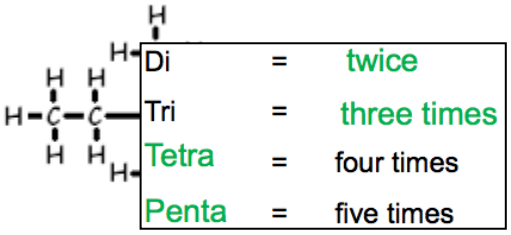
NAMING BRANCHED ALKANES

Step 1: Find the longest continuous chain of carbons (parent chain) – this the "last name"
Step 2: Identify and name the side chains (alkyl groups not on the parent chain)
Step 3: Number the carbons in parent chain starting with the end that will give the attached alkyl groups the smallest numbers.
Step 4: Add numbers to the names of the groups to identify their positions on the chain.
Step 5: List the alkyl groups in alphabetical order.

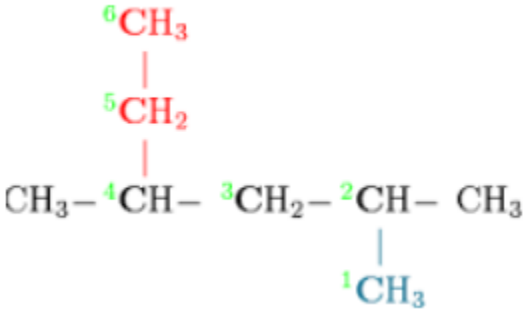
EXAMPLE:



Name: 4-ethyl-2- methyl heptane
**** Use prefixes if a group appears more than once in the structure.

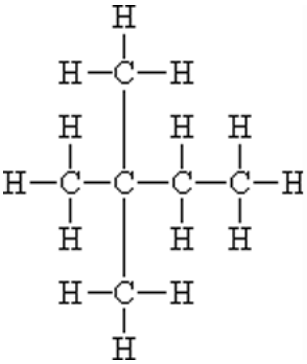


EXAMPLE: Name the following compound (Remember find the longest chain first) --



Name:

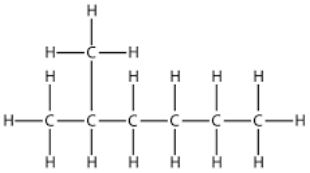
EXAMPLE:



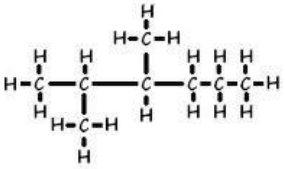
Name:

Check your understanding:

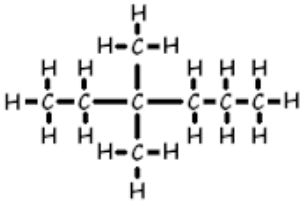
What is the name of the following:



What is the name of the following:



Name the following:



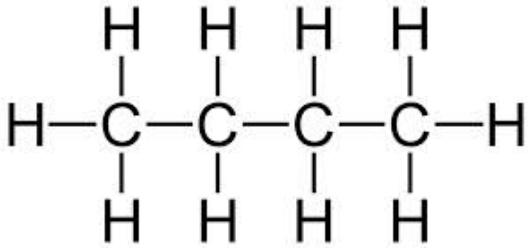
Objective:

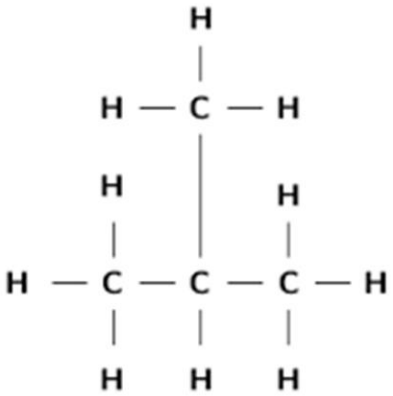
- ***Identify and construct isomers of alkanes, alkenes and alkynes***

ISOMERS OF ALKANES

ISOMERS: Have the **same molecular formula** but rearranged in a **different structure** with different properties.

EXAMPLE: Both C_4H_{10}

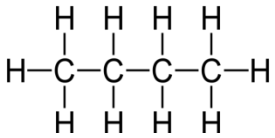


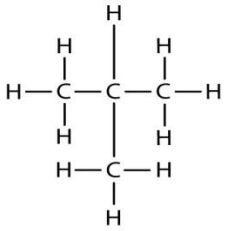


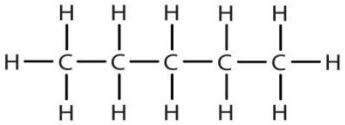
Name: Butane

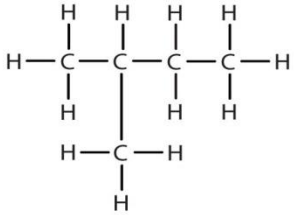
Name: 2-methyl propane

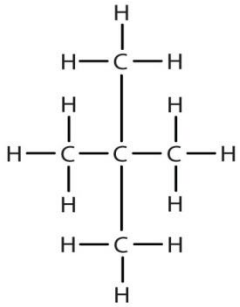
EXAMPLE: Match the Isomers:





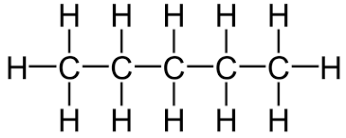


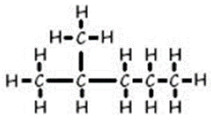


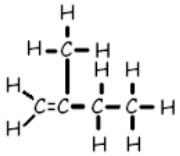


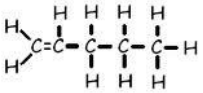
Check your understanding:

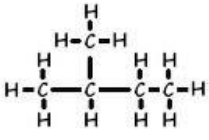
Which of these is an isomer of:











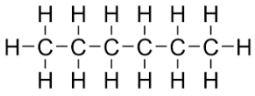
Lesson 4: Isomers of Hydrocarbons

Drawing an Isomer of an alkane:

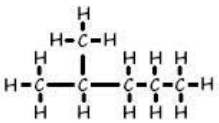
- Use same molecular formula
- Draw a different structural formula

(if name of compound is different but it has the same molecular formula it is an isomer

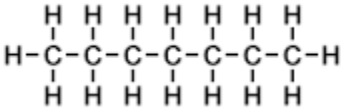
EXAMPLE: Draw an isomer of hexane

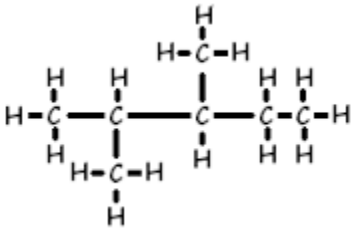


Isomer
2-methyl pentane

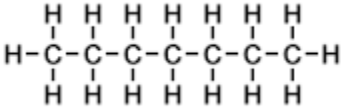


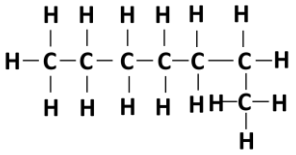
Check your understanding:
Are these isomers?





What about these?

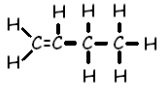




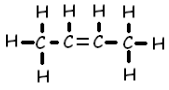
Isomers of Alkenes/Alkynes

- Double or Triple bond in different locations

Example: Isomers of butene



1-butene



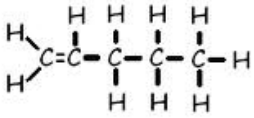
2-butene

Drawing an isomer of an alkene/alkyne

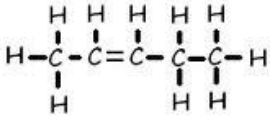
- Use same molecular formula
- Move the location of the double or triple bond

****Be careful not to move it into the same position. Remember you can read compounds left to right or right to left.

EXAMPLE: Draw an isomer of 1-pentene



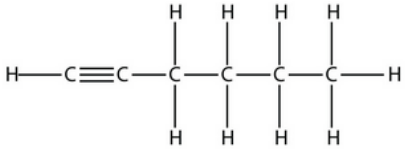
1-pentene

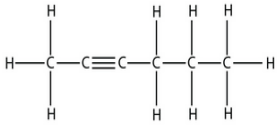


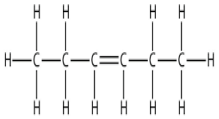
2-pentene

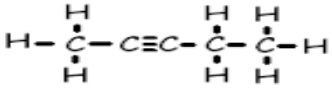
Check your understanding:

Which of the following is an isomer of:

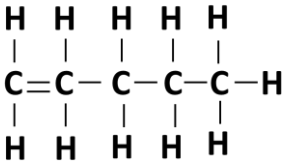


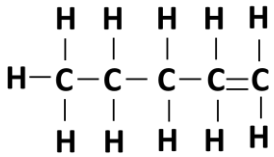






Are these isomers?





Lesson 5: Functional Groups

Objective:

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

To **NAME** or **DRAW substituted hydrocarbons:**

- Use the example given in table R and compare to your problem.
- Locate the class of compound and see how it is named or drawn in the example:
- Use it as a model to draw or name your problem

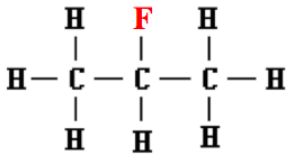
FUNCTIONAL GROUPS (TABLE R)

HALIDES:

- Have one of the halogens as a branched group.
- Name chain
- Add halogen prefix
- # location of halogen

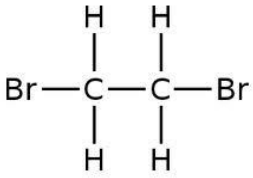
halide (halocarbon)	—F (fluoro-) —Cl (chloro-) —Br (bromo-) —I (iodo-)	*R*—*X* (*X* represents any halogen)	$CH_3CHClCH_3$ 2-chloropropane

EXAMPLE:



Name: 2- fluoropropane

EXAMPLE: If more than one of the same halogen use di,tri etc.



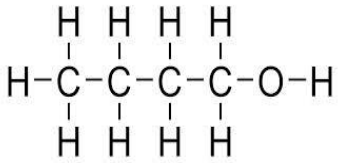
Name: 1, 2-dibromoethane

ALCOHOL:

- Functional group (OH) <u>but not a base</u>
- Name parent chain
- Suffix -ol
- # location of OH

alcohol	−OH	$R-OH$	$CH_3CH_2CH_2OH$ 1-propanol

EXAMPLE:



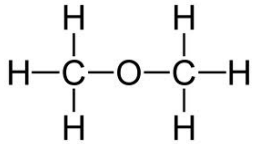
Name: 1-butanol

ETHER:

- Name small chain then large chain
- <u>suffix</u>: -ether

ether	−O−	$R-O-R'$	$CH_3OCH_2CH_3$ methyl ethyl ether

EXAMPLE:



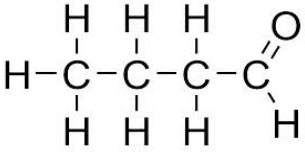
Name: Dimethyl ether

ALDEDYDE:

- Name chain
- Suffix: al

aldehyde	$-\overset{\overset{O}{\|\|}}{C}-H$	$R-\overset{\overset{O}{\|\|}}{C}-H$	$CH_3CH_2\overset{\overset{O}{\|\|}}{C}-H$ propanal

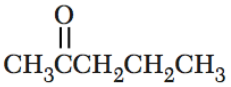
EXAMPLE:



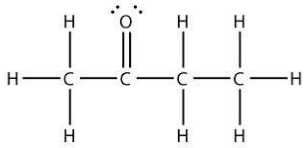
Name: butanal

KETONE:

- Name parent chain
- Suffix: -one
- # location of functional group

ketone			 2-pentanone

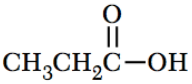
EXAMPLE:



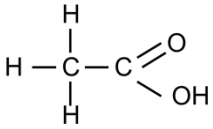
Name: 2- butanone

ORGANIC ACIDS:

- Name parent chain
- Drop ending and add -oic acid

organic acid			 propanoic acid

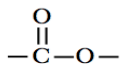
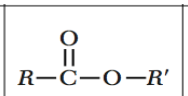
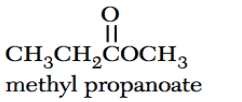
EXAMPLE:



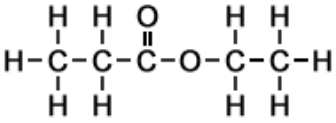
Name: Ethanoic acid

ESTER:

- Name chain bonded to O first
- Name chain with double bond =O last
- Suffix: -anoate

ester			 methyl propanoate

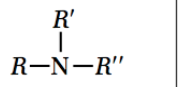
EXAMPLE:



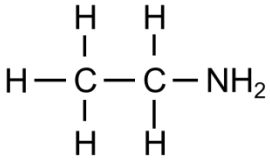
Name: Ethyl propanoate

AMINE:

- Name chain
- Suffix: amine

amine			$CH_3CH_2CH_2NH_2$ 1-propanamine

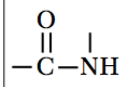
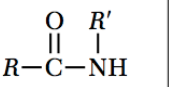
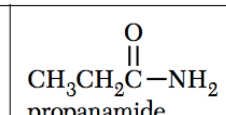
EXAMPLE:



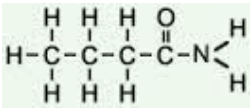
Name: ethanamine

AMIDE:

- Different than amines due to double bonded =O
- Name parent chain
- Suffix: amide

amide			 propanamide

EXAMPLE:



Name: butanamide

Lesson 6: Organic Reactions

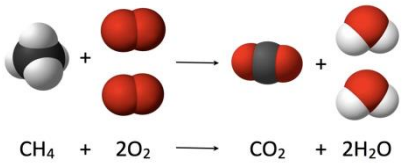
Objective:

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

ORGANIC REACTIONS: How organic molecules are formed

1. **COMBUSTION:**
   - ALKANE is burned in the presence of oxygen to produce CO_2 and H_2O
   - **Oxygen** is always a **reactant**

First 6 reactions in Table I

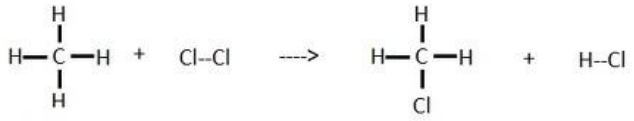


2. **SUBSTITUTION:**
   - Similar to single replacement: two atoms switch
   - First compound is **saturated (single bonds)**
   - One H is switched (SUBSTITUTED) with one Halogen (group17).

Reactant is an Alkane

Product is a Halide

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

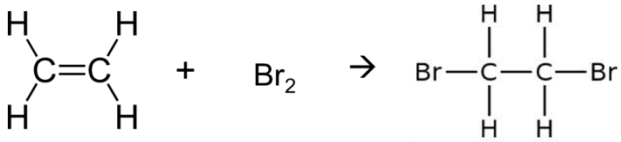


3. **ADDITION:**
   - Double or Triple Bond is broken and two or more atoms are added
   - Molecule must be **unsaturated**

Reactant is an Alkene (or Alkyne)

Product is a Halide

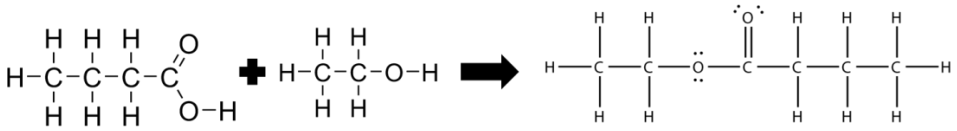
$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$



4. **ESTERIFICATION:**

Alcohol and Acid react to form Ester

- Forms esters (smells)
- **Identify Ester as a product (Use TABLE R)**



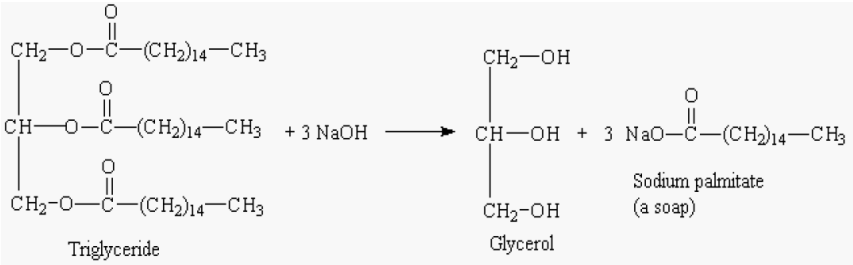
5. **FERMENTATION:**
   - Enzymatic breakdown of sugar into alcohol (ethanol) and CO_2
   - Identify **alcohol and CO_2 as a product**

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Sugar ferments to form alcohol and CO_2

6. **SAPONIFICATION:**
   - Hydrolysis of fats using a base
   - Produces soap and glycerol (alcohol)
   - **Identify soap as product and base as reactant**

Product is soap; usually involves NaOH



- must use Table R to identify these!
- Reaction is VERY COMPLICATED looking

7. **POLYMERIZATION:**
   - Formation of long-chain molecules (polymers) from small repeating subunits (monomers)
   - 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

Product is long chain

ADDITION POLYMERIZATION:

- Adding small alkenes together by breaking the double bond, to create a large chain.

- Identify by **"n"** which represents a **large number**

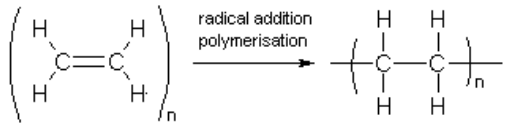


Fig 1: The polymerisation of ethene in to poly(ethene)

CONDENSATION POLYMERIZATION:

- Joining 2 molecules by removing **water**