

*Chemistry is Life is Chemistry is Life Chemistry is Life is Chemistry is Life is*

*Chemistry is Life* Chemistry is Life Chemistry is Life

Chemistry is Life is Chemistry is Life Chemistry is Life is

Awwh, man!!!  
I think I stepped in something!!

Don't worry,  
I think it's organic..

hee, hee, hee  
hee, hee, hee

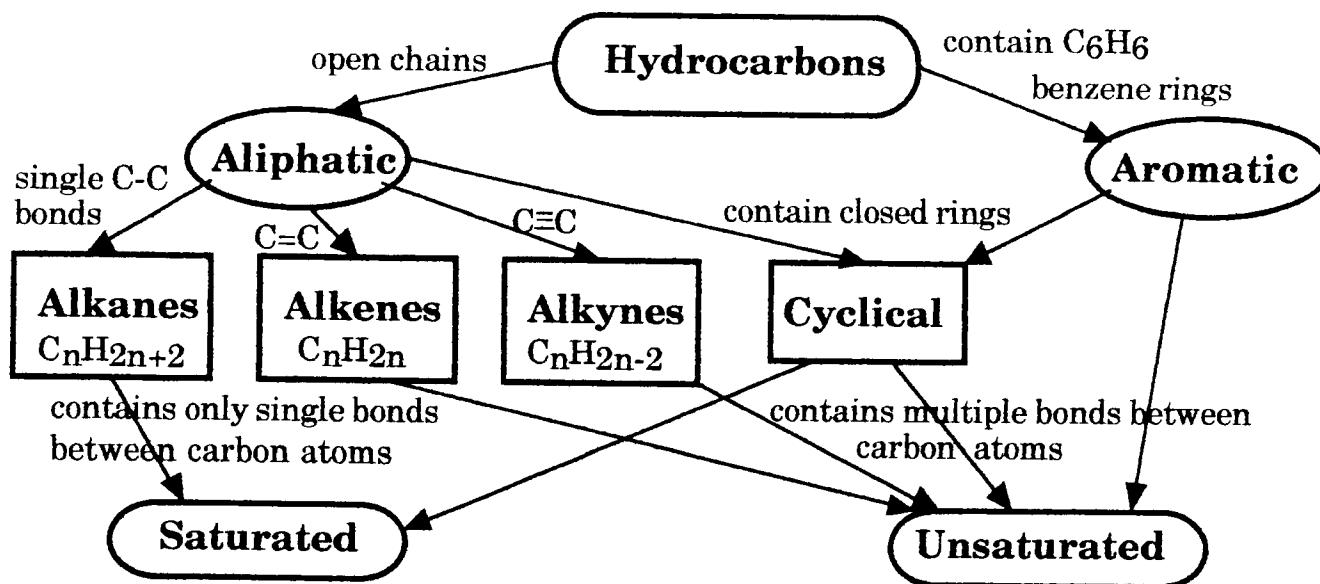
Unit



## Unit 12: Organic Chemistry

### I. Chemistry of CARBON compounds

- A. **Organic chemistry** deals with primarily all substances that contain carbon. Originally it was based on the study of substances from living organisms, because these substances could only be obtained by isolation from plants or animals, or from petroleum and coal. Today, thousands of new organic compounds are synthesized each year in the laboratory without the aid of any living organisms. Millions of organic compounds exist as a result of carbon's ability to:
1. share its 4 valence electrons
  2. form single, double, and triple covalent bonds
  3. form a seemingly endless array of bonds with itself and other elements
- B. Comparison of organic versus inorganic compounds with regard to:
1. solubility- organic compounds dissolve in nonpolar solvents, such as hexane, but *not* in water; inorganic compounds are usually water soluble.
  2. combustibility- organic compounds will burn to form  $\text{CO}_2$  and  $\text{H}_2\text{O}$ ; most inorganic compounds do not burn easily, and if they do burn, they only form the oxides.
  3. rate of reactions- organic reactions are very slow and usually need a catalyst to speed up the chemical changes; most inorganic reactions are instantaneous, such as a precipitation reaction.
  4. type of bonding- there is mainly nonpolar covalent bonding in organic compounds, with a few polar bonds; many inorganic compounds are ionic or highly polar covalent.
  5. isomerism- can form many different organic compounds that have the same molecular formula, but different structural formulas; inorganic compounds have one specific formula.
- C. In order to try to organize and classify the millions of organic compounds that exist, chemist have developed a set of very specific rules for naming these compounds. The simplest types of organic compounds contain only carbon and hydrogen atoms (called **hydrocarbons**). All subsequent naming of more complex compounds is based on the classification of these hydrocarbons shown below:



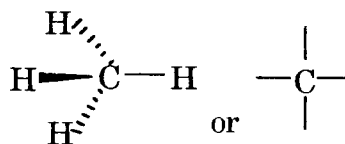
### Problem:

The naphthalene in moth balls, the paraffin in candle wax and the oleic acid in vegetable oil are all examples of organic compounds. What properties do all of these compounds have in common?

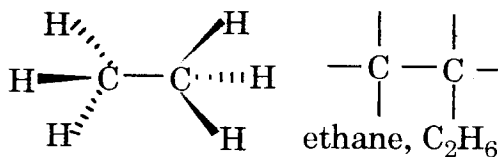
## II. Alkanes

- A. **Alkanes** contain only carbon-carbon single bonds and are therefore considered to be *saturated* in terms of having the maximum number of bonds possible. Each carbon atom will have 4 bonding areas around it to create a repeating tetrahedral-shaped molecular structure.

For example,  $\text{CH}_4$  is the simplest alkane and is called methane. The structural formula is shown at the right, but chemists will usually draw a 2-dimensional structure that has the hydrogen atoms omitted, like the structure at the far right.



It is difficult to represent all of the proper angles that exist between the atoms, and the molecule can rotate around the C-C bonds anyway, so the 2-dimensional structure is sufficient.



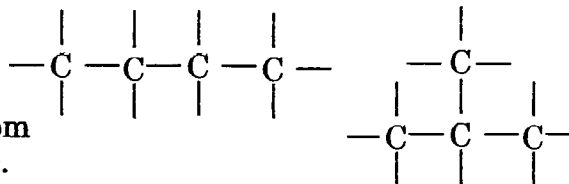
The names of the various alkanes are based upon the number of carbon atoms that are connected together in the longest continuous chain. All of the alkane names end with the suffix **-ane**. Since the names of most of the other organic compounds are derived from the basic alkane structure, you should memorize the list of alkane names and formulas below:

$\text{CH}_4$  **methane**    $\text{C}_2\text{H}_6$  **ethane**    $\text{C}_3\text{H}_8$  **propane**    $\text{C}_4\text{H}_{10}$  **butane**    $\text{C}_5\text{H}_{12}$  **pentane**  
 $\text{C}_6\text{H}_{14}$  **hexane**    $\text{C}_7\text{H}_{16}$  **heptane**    $\text{C}_8\text{H}_{18}$  **octane**    $\text{C}_9\text{H}_{20}$  **nonane**    $\text{C}_{10}\text{H}_{22}$  **decane**

\* Note that beginning with pentane, the name of the alkane is derived from a prefix that indicates how many carbon atoms are present in the longest continuous chain.

- B. **Structural isomers** exist for any alkane that has 4 or more carbon atoms in its molecular formula. A structural isomer is an organic compound that has the same molecular formula as another compound, but different structural formulas because of the arrangement in which the carbon atoms are bonded together.

For example, butane has the molecular formula of  $\text{C}_4\text{H}_{10}$  and can exist as either a chain of 4 carbon atoms in a row or as a 3 C-atom chain with a fourth carbon atom attached in the middle (far right structure).



A condensed method of drawing butane's structural formula is  $\text{CH}_3\text{—CH}_2\text{—CH}_2\text{—CH}_3$

The structure on the right is described as a branched hydrocarbon, and it is actually named as a form of propane, because the longest continuous chain has 3 carbon atoms. The greater the number of carbon atoms in the compound, the more structural isomers that exist. The butane shown above has only 2 structural isomers, but hexane has 5, octane has 18, and  $\text{C}_{10}\text{H}_{22}$  has 75 different isomers!!!

**Problem:**

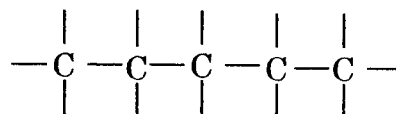
Draw the 5 different structural isomers that exist for hexane,  $C_6H_{14}$ .

**III. IUPAC Nomenclature(naming) of the Alkanes**

Since there are so many different possible structures for organic compounds, the International Union of Pure and Applied Chemistry(IUPAC) worked together to develop a specific set of guidelines used worldwide for naming and identifying organic compounds. The following rules apply when naming the alkanes:

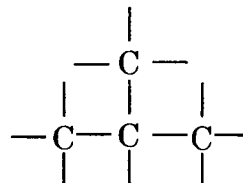
**Rule 1:** Determine the number of carbon atoms in the longest continuous chain(called the parent chain) and name that alkane.

Example: An alkane that has 5 carbon atoms bonded in a row is simply named *pentane*.

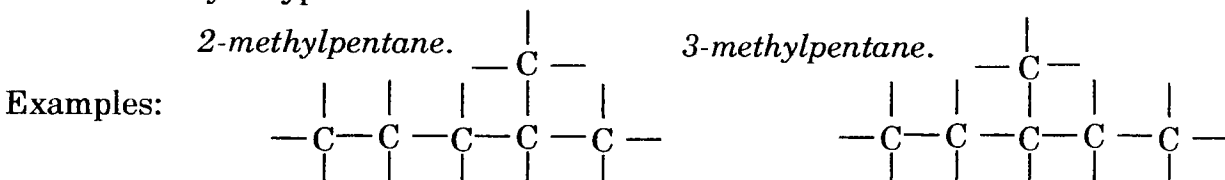


**Rule 2:** If a branched chain is present, first select the parent chain(the longest) and name it. The attached carbon groups(branches) are referred to as alkyl groups and their -ane suffix is changed to the suffix **-yl**. Add the names of these alkyl groups as a prefix to the name of the parent chain.

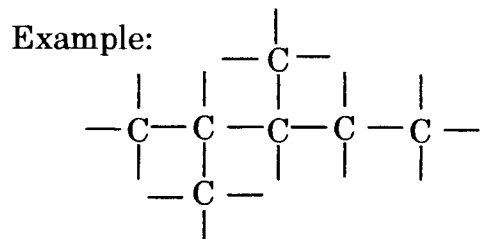
Example: *methylpropane* would have the structure shown at the right, having a one-carbon branch attached to a 3-carbon parent chain.



**Rule 3:** If there is more than one possible location for an alkyl group to attach onto the parent chain, then use the lowest number(or combination of numbers) possible to locate the attached group. This is done by numbering the carbon atoms in the parent chain, starting from the end that produces the lowest numerical values. The numbered location is listed first and is separated from the alkyl name by a hyphen.

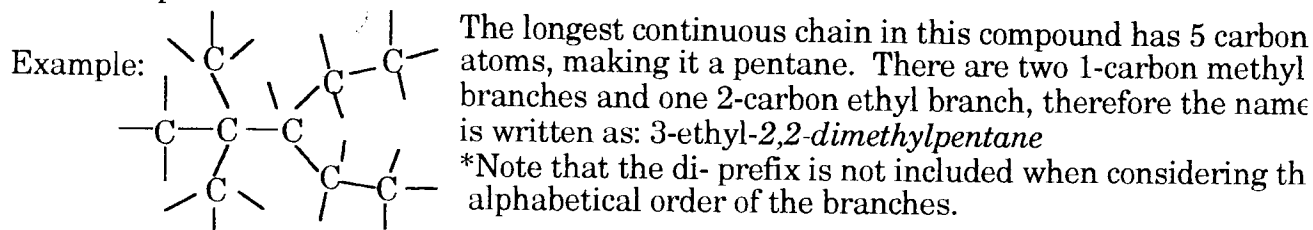


**Rule 4:** Use the prefixes di-, tri-, tetra-, etc. to identify when there are 2 or more of the same type of alkyl groups attached to the parent chain. Each branch needs its own numerical location, when necessary, making sure to use the lowest combination of numbers. The subsequent numbers are separated by commas.



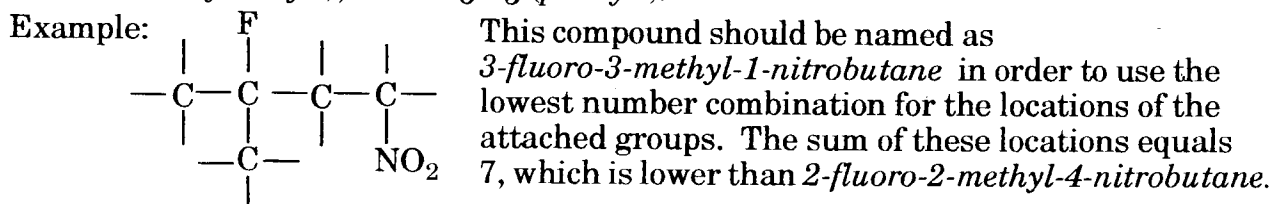
This compound should be named *2,3-dimethylpentane* and NOT *3,4-dimethylpentane* in order to use the lowest number combination for the locations of the attached methyl groups.

**Rule 5:** When a compound contains alkyl branch groups of different lengths, list each group alphabetically. Do not include any prefixes when considering the alphabetical order.

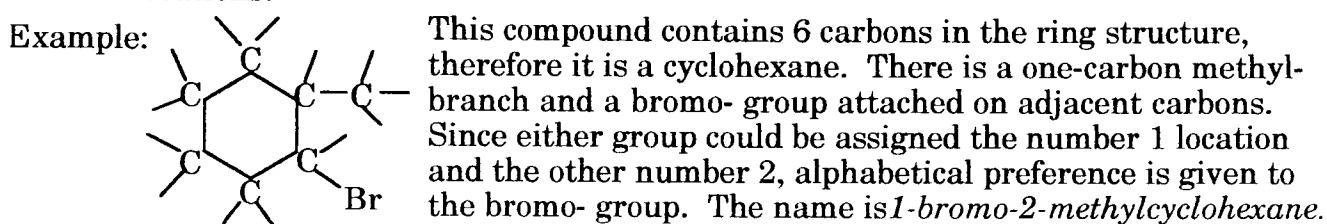


\*Note that the di- prefix is not included when considering the alphabetical order of the branches.

**Rule 6:** Other elements or substituted groups can also be attached to the parent chain, and they should be treated the same as the alkyl groups. Identify their location with the lowest possible number, list them in alphabetical order and use di-, tri-, .... prefixes for several of the same group. The most common substituted elements are the reactive halogens. When F, Cl, Br or I are attached to the parent chain, they are identified by the prefixes *fluoro-*, *chloro-*, *bromo-* and *iodo-*, respectively. Typical attached groups also include -NO<sub>2</sub>(*nitro-*), -NH<sub>2</sub>(*amino-*), -OH (*hydroxyl-*), and -C<sub>6</sub>H<sub>5</sub> (*phenyl-*).



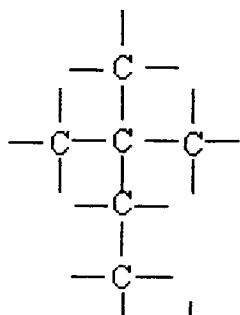
**Rule 7:** When two hydrogen atoms are removed from different carbon atoms near the ends of an alkane, the carbons can bond together to form a ring structure called a **cycloalkane**. The ring structure is considered to be the parent chain and the prefix "cyclo-" is added to its name. The ring carbons are numbered so that any alkyl or substituted groups that are attached have the lowest set of numbered locations.



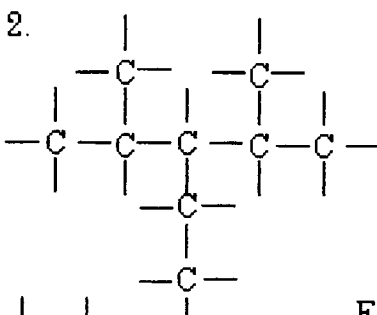
### Problems:

Draw the structural formulas or name the following compounds:

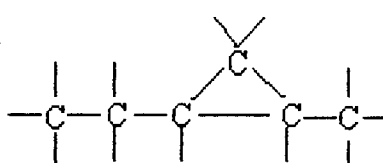
1.



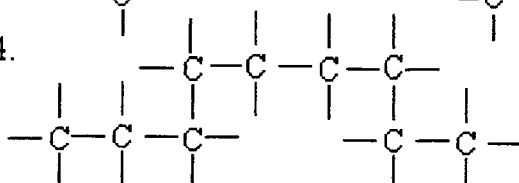
2.



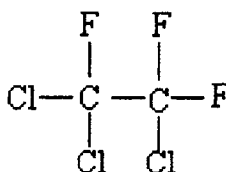
3.



4.



5.



6. 2,3,5-trimethylhexane

7. 2-amino-1-hydroxybutane

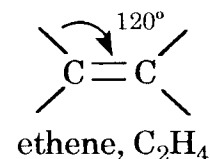
8. 3,4-diethyl-2-methyloctane

#### IV. Alkenes and Alkynes.....Unsaturated Hydrocarbons

Alkenes and alkynes are hydrocarbons that contain double and triple multiple bonds, respectively, between the carbon atoms. These compounds are said to be unsaturated because it is possible for more atoms to bond onto the chain at these chemically reactive sites with high electron density. The presence of a multiple bond in any organic structure determines specific predictable properties of the molecule, therefore the multiple bond is classified as one type of **functional group**.

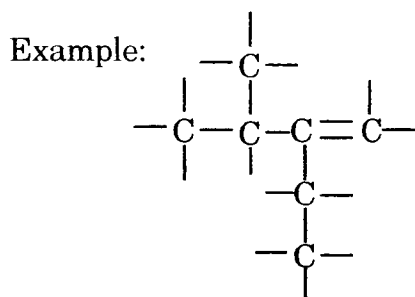
- A. **Alkenes** have at least one double C=C bond in their structure, and have the general formula of  $C_nH_{2n}$  (Note that there are 2 less hydrogen atoms than in the alkane structure.) A double bond forms when two hydrogen atoms are removed from adjacent carbon atoms in an alkane structure, so that the carbons can maintain a valence shell octet. This double bond changes the geometry of the carbon chain to produce a reaction site for substances looking for extra electrons, such as the halogens.

The  $120^\circ$  angles between the 3 bonding areas around the double bonded carbon atoms produces a trigonal planar shaped structure. This arrangement is more rigid than single bonded carbons, holding the attached atoms more securely in their relative positions.



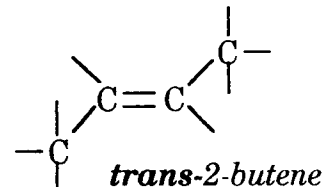
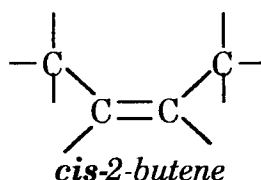
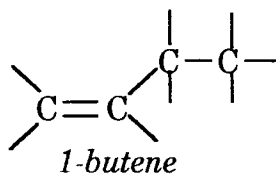
- When naming the alkenes the same general rules apply as for the alkanes with the following modifications:

The parent chain **must** include the double bond(s), even if this is physically not the longest continuous chain possible. Use the same prefix names as the alkanes, but change the -ane suffix to **-ene**. A number immediately precedes the name of the main chain to indicate the position of the double bond, when more than one location is possible. The location of any multiple bonds takes priority over the numbering of any branches or substituted groups that may be attached to the parent chain. Geometric isomers can exist when the attached groups are on the same side of the molecule across the double bond or on opposite sides. A prefix of **cis**-(same side) or **trans**-(opposite side) is sometimes added to the alkene name to indicate the actual orientation.

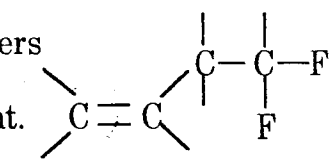


In this structure, the longest continuous chain possible would contain 5 carbon atoms (the vertical chain). However, that pentane structure would not include the double bond area, which has priority in determining the parent chain. The actual structure is a butene with an ethyl- and a methyl-branch. Since the multiple bond takes priority in numbering the correct name is *2-ethyl-3-methyl-1-butene*.

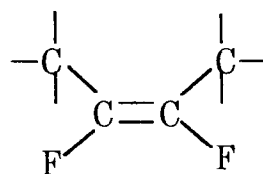
Examples:  
The 3 isomers of  $C_4H_8$  are shown at the right.



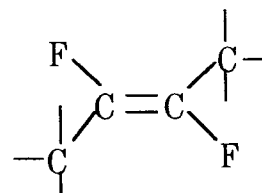
Some of the isomers for  $C_4H_6F_2$  are shown at the right.



4,4-difluoro-1-butene  
a polar molecule



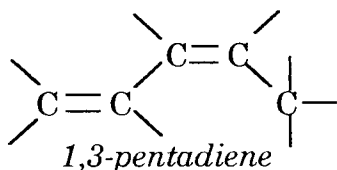
cis-2,3-difluoro-2-butene  
a polar molecule



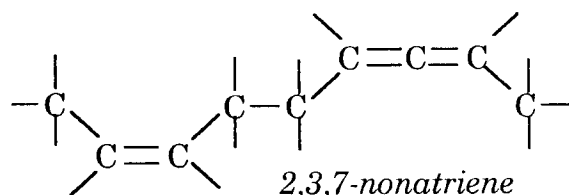
trans-2,3-difluoro-2-butene  
a nonpolar molecule

In some larger alkenes, there can be more than one double carbon bond site. As with the substituted groups, each bond must be identified by some modification of the parent name and a number to locate its position. The prefixes *di-* and *tri-* are used with the -ene suffix to indicate two or three C=C bonds are present, which occur in **alkadienes** and **alkatrienes**.

Examples:



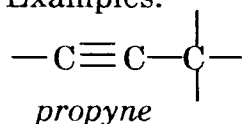
1,3-pentadiene



2,3,7-nonatriene

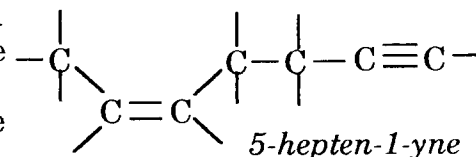
- B. **Alkynes** have at least one triple C≡C bond in their structure, and have the general formula of  $C_nH_{2n-2}$  (Note that there are 4 less hydrogen atoms than in the alkane structure.) A triple bond also changes the geometry of the carbon chain, making it linear across the bond. Reactive nonmetals can break one or two of these multiple bonds and bind onto the hydrocarbon chain. When naming an alkyne, the suffix **-yne** is added to the parent chain's name, which is preceded by a number to indicate the bonds location. With two and three triple bonds present, the suffixes *-diyne* and *-triyne* are added to the parent alkane name.

Examples:



propyne

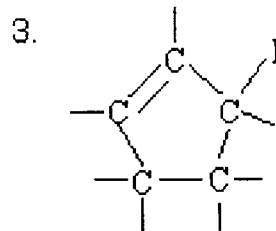
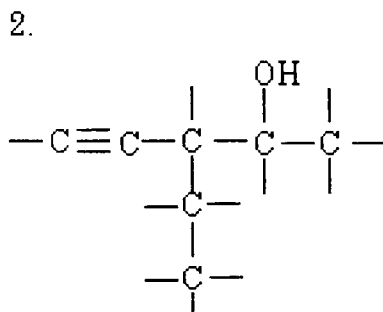
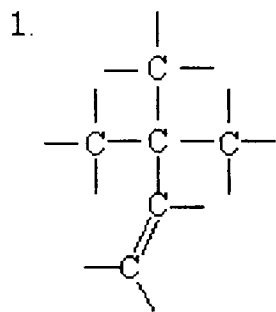
The propyne on the left doesn't need a number to locate the bond site. In the structure at the right, there is both a double and triple bond, so both the *-ene* and *-yne* suffixes are used.



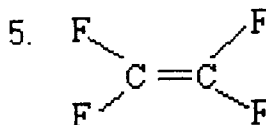
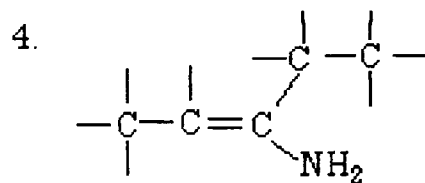
5-hepten-1-yne

### Problems:

Draw the structural formulas or name the following compounds:



6. 4,5-dibromo-2-pentene



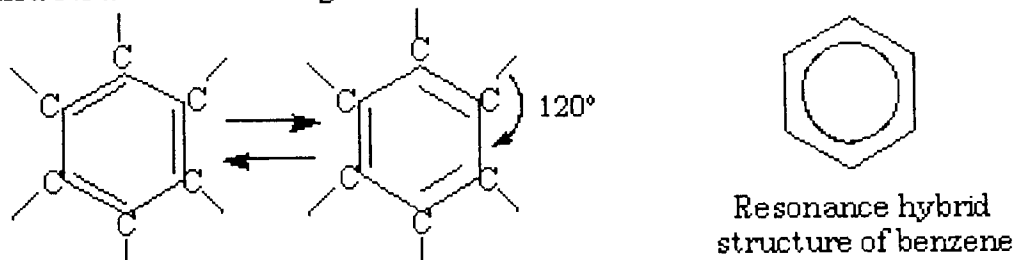
7. 3,3-dimethyl-1,4,6-octatriene

8. 3-ethyl-5-nitro-1,3-pentadiene

## V. Aromatic Hydrocarbons.....Benzene Ring Structures

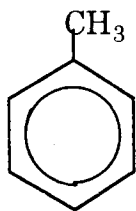
The aromatic hydrocarbons are based on compounds that contain  $C_6H_6$  ring structures, in which 3 double bonds are being shared between all six carbon atoms. Benzene's structure indicates that the shared double bonds can change positions within the ring, as indicated by the two resonance structures on the next page. The  $120^\circ$  angles between the three areas of charge around each carbon atom create a molecule that is two-dimensional(trigonal planar). The double bonded electrons are delocalized in a way similar to metal structures. Chemists usually represent the benzene ring by a hexagon with a circle inside of it.

The 2 possible resonance structures of benzene shown on the left are usually represented by the simplified structure on the right.

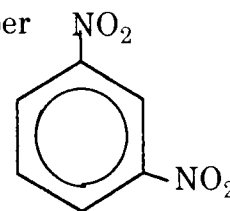


A benzene compound containing any substituted groups is usually named by the previously discussed rules for identifying and locating the groups, and ends with the name *benzene* as the parent chain. Numbering is based upon one of the groups being attached to carbon #1, then counting either clockwise or counterclockwise around the ring to determine the location of the other groups.

Examples: The compound on the right has a methyl group attached to the benzene ring, therefore it is named as *methylbenzene*. (a.k.a. toluene)

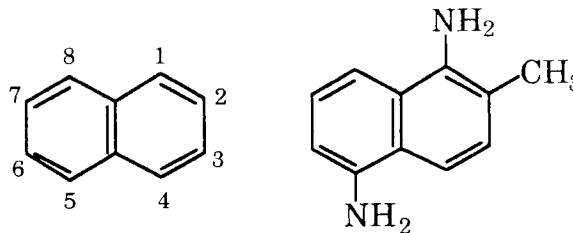


Always use the lowest number combination to indicate the relative positions of the attached substituted groups to each other. This is *1,3-dinitrobenzene*.



More complicated aromatic structures can be made when two or more benzene rings link together by sharing a common double bond site. In these situations, it is easier to give the combined structure a new name, such as *naphthalene* ( $C_{10}H_8$ ), rather than calling it a *dibenzene*. The numbering of the carbon atoms in these larger aromatic compounds follows the outer edges of the ring structures in a specific pattern.

Example: The numbering of the carbon chain for naphthalene is shown at the right, and the name of the compound in this example is *1,5-diamino-2-methylnaphthalene*.



### Problems:

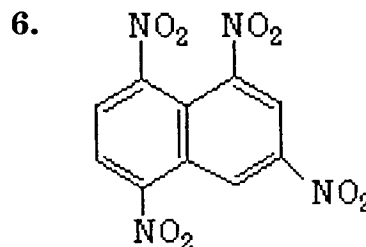
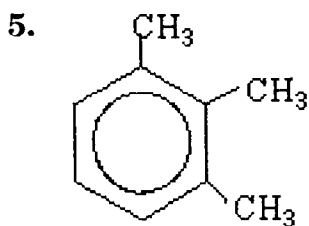
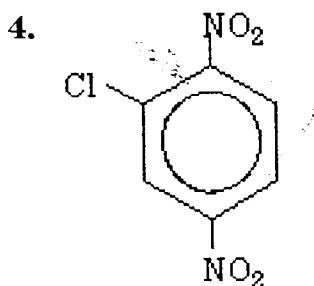
Draw the structural formulas or name the following compounds:

1. 1,2,4,5-tetraethylbenzene

3. 3-chloro-8-nitronaphthalene

2. 3,4-dibromo-2-phenyl-1-butene



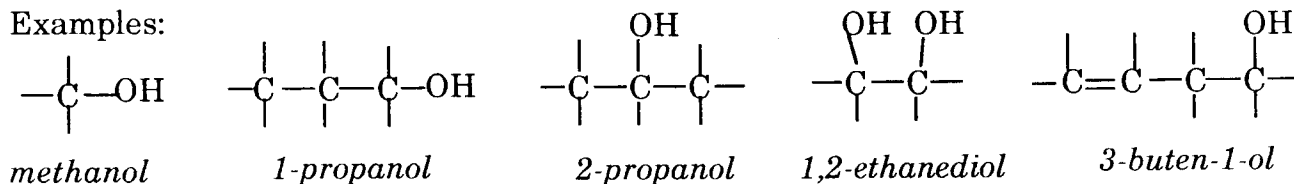


## VI. Other Functional Groups Containing Oxygen & Nitrogen

The hydrocarbons can also contain oxygen and nitrogen atoms arranged in a variety of bonding combinations. Each change in composition or structural arrangement produces a new type of organic compound with specific chemical and physical properties, and of course, a new method of naming the compound. Like the multiple bond sites, these attached atoms or groups of atoms are also classified as functional groups because they result in predictable characteristics of the compounds that contain them. When representing the general structures of these organic compounds, the letter **R-** is used to indicate the rest of the molecule to which the functional group is attached. R- may be a single carbon atom or a larger hydrocarbon structure. When determining the numbering of the parent chain in order to locate group positions, the functional groups with oxygen or nitrogen take priority over the locations of multiple bonds or other substituted groups, such as the halogens or alkyl groups.

- A. **Alcohols** (R-OH) contain the -OH (*hydroxyl-*) group attached to any carbon in the compound. In more complex compounds, the -OH is treated like any other substituted group and named as a *hydroxyl-* group. In simpler compounds where the -OH is the most reactive site, the suffix *-ol* is added in place of the last "e" in the name of the parent chain. The -OH position is indicated by a number, when necessary. There can also be two or more *hydroxyl-* groups attached to the chain, so the suffixes *-diol*, *-triol*, etc. are added to the parent name to indicate this structure.

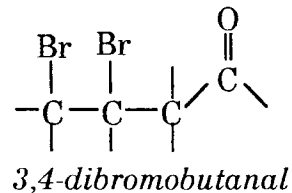
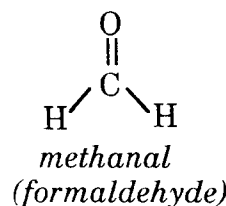
Examples:



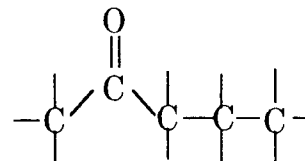
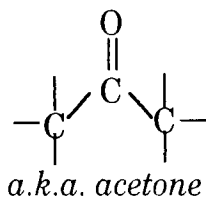
The polar structure of the -OH group can form hydrogen bonds with other polar molecules, such as water. Therefore, the alcohols with fewer carbon atoms, such as methanol and ethanol, are very water soluble. As the carbon chains get longer with 4 or more carbons, the nonpolar ends interfere with the hydrogen bonding, and the solubility decreases. Alcohols can be considered to be the bases of organic chemistry, because the -OH groups are capable of accepting protons ( $H^+$  ions) from acidic compounds, such as  $HCl(aq)$ . The -OH groups can also be a site for oxidation reactions on the carbon chain to form aldehydes or ketones.

- B. **Aldehydes** and **ketones** both contain the carbonyl group ( $C=O$ ). The distinction between them is that the carbonyl group is attached at the end of the chain in the aldehydes and somewhere in the middle of the chain for the ketones. Typically, both groups are formed by the oxidation of alcohols, which removes the H atom and forms another bond with the O.

The carbonyl group in the aldehydes is considered to be carbon #1 for numbering purposes and the name is derived by replacing the last -e of the parent chain with the suffix *-al*. No number is needed to locate the position of the carbonyl group.



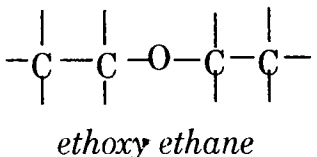
In larger ketones, the carbonyl group may need a number location. The suffix *-one* is added in place of the last -e of the parent chain. The compounds on the right are called *propanone* and *2-pentanone*, respectively.



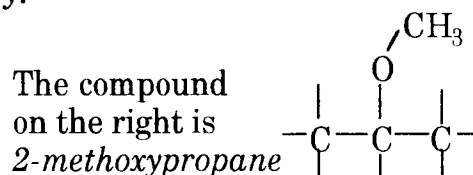
The polar bonds between the oxygen and the carbon in the carbonyl group provides a site of reactivity in an otherwise stable hydrocarbon chain.

C. **Ethers** (R-O-R) contain an oxygen atom bonded as a bridge between two hydrocarbon groups. The C-O bonds are not as polar as the -OH group of the alcohols, and there is no hydrogen bonding between neighboring molecules. Therefore, the ethers vaporize easily, have low boiling points, and are not water soluble. Often they are used as solvents for fats and oils. Ethers are named by considering the shorter chain to be a substituted alkoxy group attached to the longer parent chain. The position of attachment is indicated by a number, where necessary.

Examples: The structure of the compound commonly called "ether" is actually named *ethoxyethane*, using the IUPAC system.

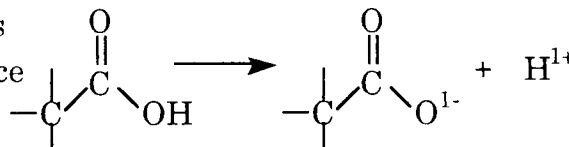


The compound on the right is

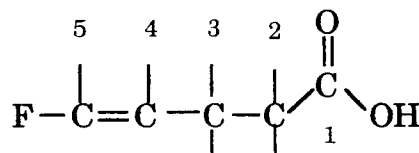


D. **Organic acids** (or carboxylic acids) contain the carboxyl group, -COOH, at the end of the parent chain. This group consists of a carbon atom with a double bond to one oxygen and another bond to an -OH group. The names of the acids are derived by replacing the final -e of the parent chain with *-oic acid*. The IUPAC name for the organic acid shown in the diagram below is *ethanoic acid*. This acid found in vinegar is commonly called acetic acid, because it consists of the ionizable hydrogen bonded to the acetate ion ( $\text{C}_2\text{H}_3\text{O}_2^{1-}$ ).

The hydrogen atom at the end of the -OH group is broken away during a chemical reaction to produce the excess  $\text{H}^{1+}$  ions characteristic of acids.



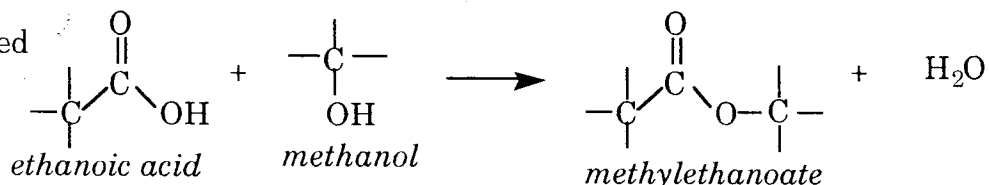
The strength of organic acids is increased when other highly electronegative atoms, such as the halogens, bond onto the carboxylic acid molecule. As a halogen pulls electrons towards itself, it draws the electrons away from the hydrogen in the carboxylic acid group making it easier to remove as the  $\text{H}^{1+}$  ion. Trichloroethanoic acid would be a much stronger acid than ethanoic acid in vinegar.



Since the carboxyl group must be at the end of the carbon chain, it will have the #1 carbon position. Any multiple bonds or substituted groups will be located by numbers based on this fact. The compound at the left is named as *5-fluoro-4-pentenoic acid*.

- E. **Esters** are produced by the reaction between organic acids and alcohols. The  $H^{1+}$  of the acid combines with the  $-OH$  group of the alcohol to form water and the ester.

This reaction is called esterification.

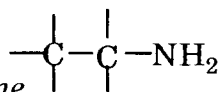


The esters are named by considering the alcohol chain to be an attached alkyl group and dropping the  $-ic$  ending from the acid name and replacing it with  $-ate$ .

Esters usually have a distinctive aroma or flavor. *Methylbutanoate* is responsible for the aroma of delicious apples, *ethylbutanoate* smells like pineapples and *pentylbutanoate* gives apricots their odor.

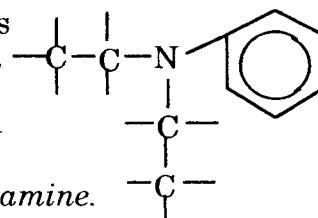
- F. **Amines** contain nitrogen bonded to alkyl groups and/or hydrogen atoms,  $R-NH_2$ . The nitrogen atom can be attached to 1, 2 or 3 alkyl groups. If the  $-NH_2$  group is bonded to a more complicated organic structure, then it can be named as the *amino*-substituted group.

This compound can be named as either *aminoethane* or *ethylamine*.



When several alkyl groups are bonded to the nitrogen, they are named in alphabetical order followed by the name *-amine*.

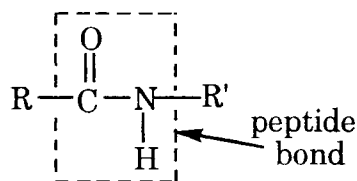
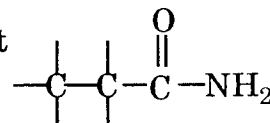
The compound on the right is called *diethylphenylamine*.



Amines are closely related to ammonia and can act like bases during chemical reactions by accepting protons ( $H^{1+}$  ions) from acids.

- G. **Amides** are characterized by having a carbonyl group bonded to the nitrogen atom of an amine group. In protein structures, this type of linkage is called a peptide bond.

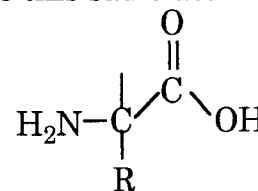
These compounds are named by dropping the final  $-e$  from the parent chain's name and adding the name *-amide*. This is *propanamide*.



A peptide bond creates a strong intermolecular force between the smaller R- sections of the compound to form long chain-like structures. Two amino acids form a peptide bond when water is removed from the  $-COOH$  and  $-NH_2$  ends of the molecules.

- H. **Amino acids** contain the carboxyl group and the amine group attached to the same carbon atom. They vary only in what the R- group is that bonds to this same atom.

Amino acids have the basic structure shown at the right. The name can be described as an *amino*- group attached to the parent carboxylic acid. For example, if the R- is an H atom, the compound would be named *aminoethanoic acid*. (common name is *glycine*)



Note that the amino acids contain both an acidic end ( $-COOH$ ) and a basic end ( $-NH_2$ ), which means they can either accept or donate protons, depending on their environment.

- I. **Nitriles** contain a nitrogen triple-bonded to a carbon atom at the end of the hydrocarbon chain.,  $R-C\equiv N$ . Just like the triple bonds in alkynes, the triple bond in nitriles is a highly reactive site. The names are derived by adding the word *-nitrile* to the end of the parent chain.

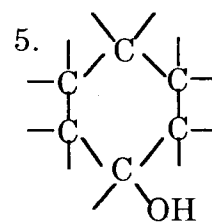
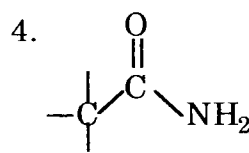
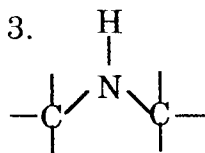
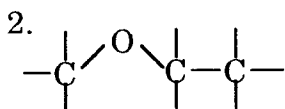
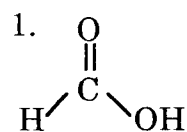
Example: This compound is called *butanenitrile*  $-C-C-C-C\equiv N$

- J. When a **nitro** group ( $-NO_2$ ) is attached to a carbon chain, it is considered to be just another substituted group and named as such.

Example: This compound is called *nitroethane*  $-C-C-NO_2$

### Problems:

Identify the type of functional group present in each and write the name or formula of:



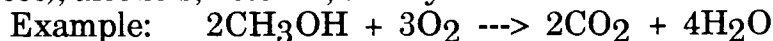
6. *1-octylethanoate*      7. *3-hexanone*      8. *2-aminopentanoic acid*

## VII. Summary of IUPAC Rules for Naming Organic Compounds

- Select the longest continuous chain containing functional groups and multiple bond(s).
- Number the carbon chain from the proper end to obtain the lowest combination of numbers based on the following order of priority:
  - Functional groups
  - Multiple bonds
  - Substituted groups
  - Alphabetical order of substituted groups
- Locate (by number) and name the substituted groups in alphabetical order. Use prefixes to indicate more than one of any particular substituted group.
- Indicate the position of any functional group(when necessary) or multiple bond(s) by number(s) immediately preceding the name of the main chain.

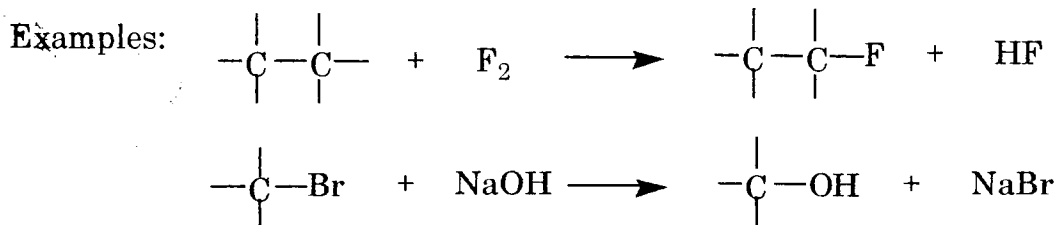
## VIII. Common Reactions of Organic Compounds

- A. **Combustion of hydrocarbons:** Alkanes are used as fuels (gasoline, diesel fuel, oil, and natural gas). They burn in excess oxygen to produce carbon dioxide gas and water in highly exothermic reactions. Partial oxidation results in carbon monoxide, carbon(soot), alcohols, ketones, aldehydes and acids.

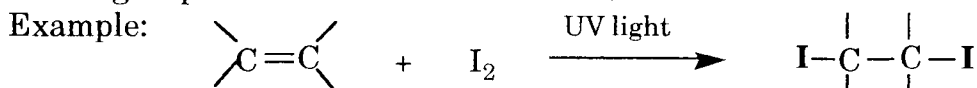


- B. **Substitution** reactions occur when one substituted or functional group replaces another in a compound. This is the primary type of reaction that alkanes

undergo to replace H atoms with other elements.

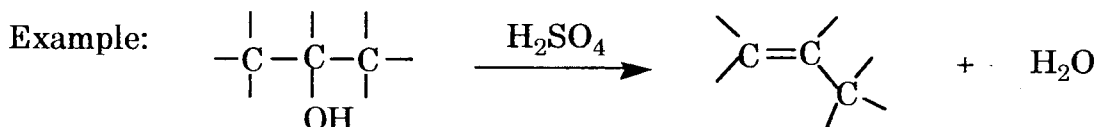


- C. **Addition** reactions are characteristic of the alkenes and alkynes. A multiple bond is broken and two groups attach to the carbon chain.

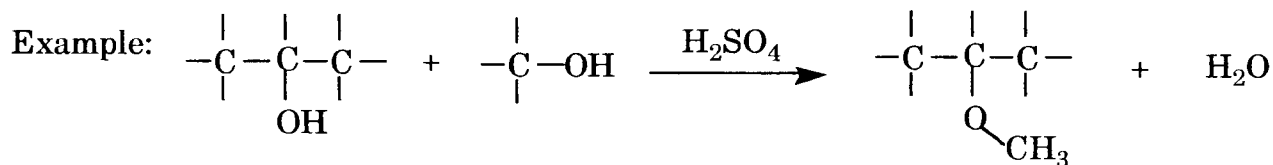


Note: this test is used to distinguish between alkanes and alkenes

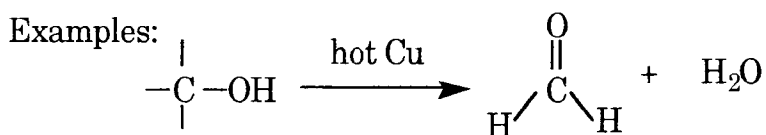
- D. **Elimination** reactions usually occur by removing a water molecule from an alcohol molecule. When this happens, a double bond is formed.



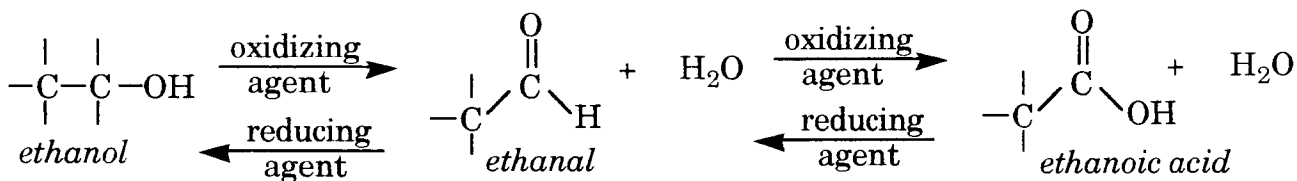
Another possible product of removing water from two different alcohol molecules is an ether.



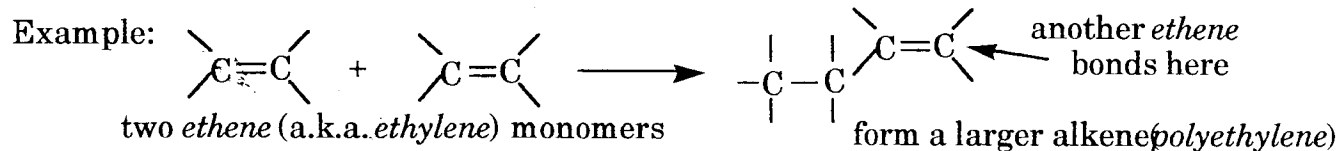
- E. **Oxidation or Reduction** of the carbon atoms in functional groups can be used to change from one functional group to another. In organic chemistry, oxidation occurs when more oxygen bonds are created with the carbon atoms (or hydrogen atoms are removed), causing the oxidation state of carbon to become more positive (indicating an apparent loss of electrons). Reduction is just the reverse of the oxidation process.



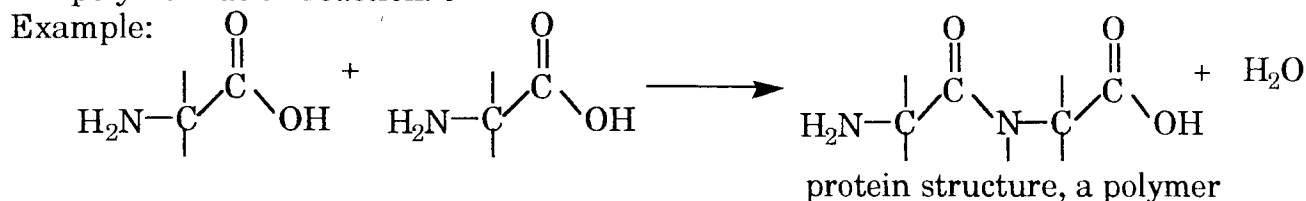
A hot Cu wire begins to form CuO. When dipped into *methanol*, the oxide removes 2 H atoms to form water and *methanal*.



- F. **Polymerization** occurs by linking smaller organic units into large chains. A single organic unit, called a monomer, bonds to other monomers in a repeating sequence throughout the chain. This chain formation is possible because even after two monomers bond, they still have another reactive site to continue the process. This method is used to make plastics and proteins. Addition polymerization reactions can occur by the adding one monomer across the double bond site of another.

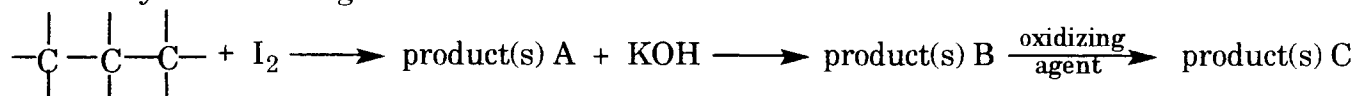


Condensation polymerization occurs when there is an elimination of atoms (usually water) between two monomers and the molecules actually condense. Note that after the two amino acids combine in the reaction below, the new protein still has the carboxyl and amine groups needed to bond again and continue the polymerization reaction.



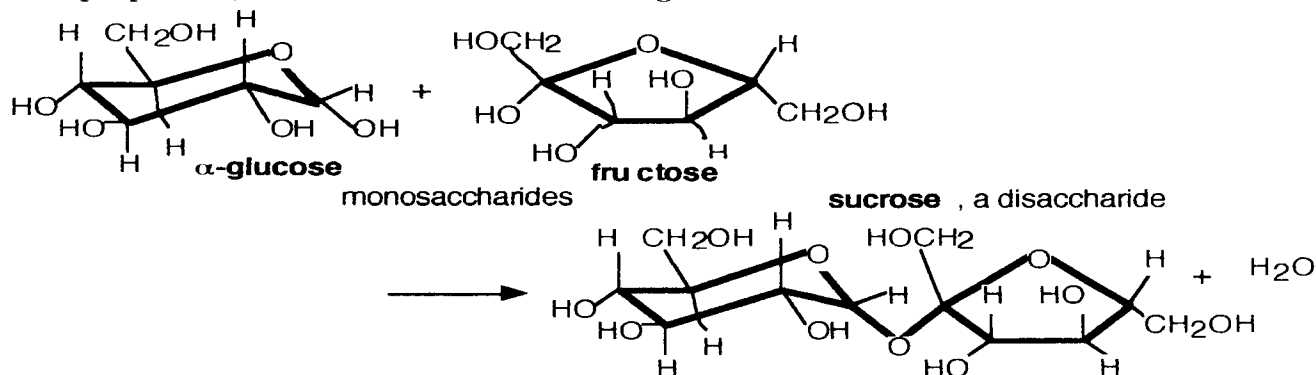
### Problems:

Determine the names and structural formulas of the possible products that could be formed by the following reactions:



## IX. Biomolecules: The Chemistry of Life

- A. **Carbohydrates** have the general formula of CH<sub>2</sub>O and include sugars, starches and cellulose. The simplest carbohydrates are the monosaccharides, glucose, fructose and galactose, which have the formula C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>. Disaccharides, such as sucrose, are made of two monosaccharide units by the removal of a water molecule. They have the general formula of C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>. Starches and cellulose are polysaccharides, which are polymers made by linking simple sugars into large, complex chains. Carbohydrates provide the fuel for all life processes. Slight differences in molecular structures cause a significant change in the carbohydrates properties, such as the sweetness of sugar versus flour.

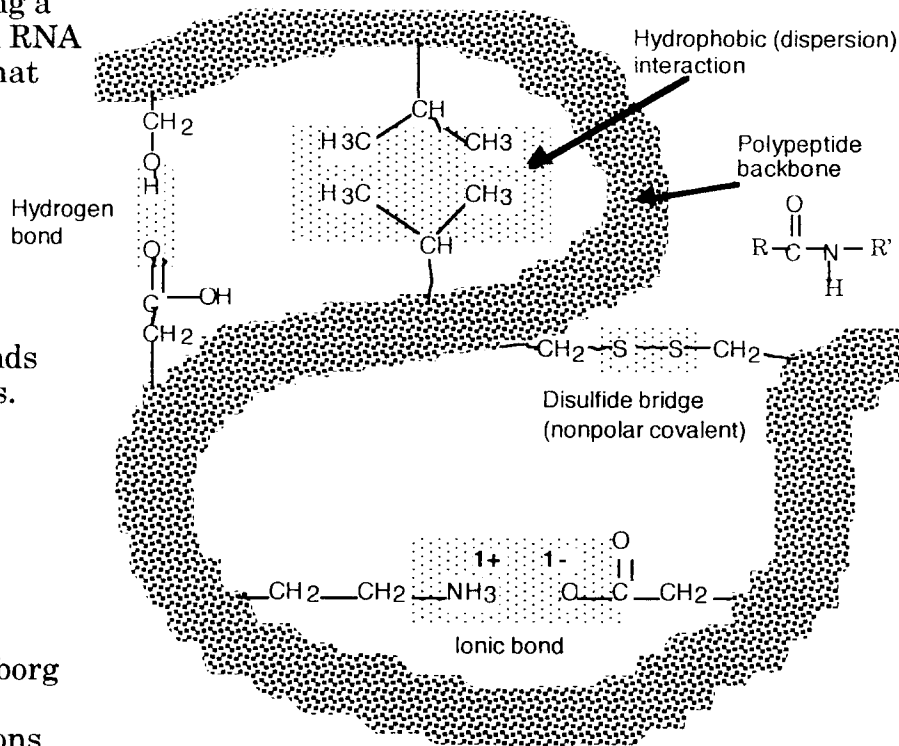


- B. **Lipids (Fatty Acids)** are long chains of carbon atoms that contain a carboxylic acid group at one end. Lipids are the storehouse for extra energy in the body. The

breakdown of fats produces twice as much energy as carbohydrates. The carbon chains can have carbon-carbon double bonds, which make it unsaturated. Eating polyunsaturated fats lowers the blood cholesterol level.

- C. **Proteins** are polymers made up of amino acids. A protein molecule is built by linking the amino group of one amino acid with the carboxyl group of another.

Water is removed leaving a peptide bond. DNA and RNA are protein molecules that exhibit cross-linking by forming hydrogen or disulfide bonds between two portions of the chain. Ionic bonding also occurs between the carboxyl and amino groups from different ends of the amino acid chains. There is even some dispersion interaction between nonpolar, hydrocarbon portions on the chain. Folding of the protein structure occurs at these sites. Proteins are a smorgasborg of bonding and intermolecular attractions.



- D. The biomolecules in the body are very specific about what they will react with, and thereby control the body functions. The body has receptor protein molecules that will react only with the other molecules of a very specific shape and polarity. Hormones and neurotransmitters act as chemical messengers in the body. Enzymes are the bodies catalysts that control the rate of chemical changes. Vitamins and minerals have specific functions that they influence.

## Unit 12 Objectives:

After completing the study guide and solving the problems you should be able to:

1. Explain the different types of bonding in carbon compounds by the overlapping of orbitals
2. Learn how to name organic compounds using the IUPAC method.
3. Learn how to recognize the different classes of organic compounds.
4. Be able to draw structural formulas for organic compounds.
5. Describe the general types of organic reactions that can occur.
6. Be able to identify the different types of biomolecules.

