I. \_\_\_\_\_\_\_\_\_ Containing Molecules

## A. The study of substances containing carbon in combination with \_\_\_\_\_\_\_\_\_ and sometimes other non-metals [O, N, S]

## B. Organic molecules are more common than all other compounds combined

## C. \_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_, vitamins are all \_\_\_\_\_\_\_\_\_\_

## D. Medical Treatment: sulfa drugs, hormones (pills, steroids), cortisone, tranquillizers, anti-inflammatants, adrenaline (epinephrine), etc.

II. Nature of Organic Molecules

## A. Bonding

1. Based on the \_\_\_\_\_\_\_\_\_\_\_ atom (each has \_\_\_ covalent bonds)

3. Single, double, triple covalent bonds between carbon atoms … also \_\_\_\_\_\_\_\_\_\_\_\_\_ (sp, sp2, sp3, etc.)

a) carbon bonds strongly with non-metallic atoms

b) carbon bonds strongly with itself

c) other atoms in the same family (group IV) like Si, Ge have relatively weak bonds with themselves

B. Characteristics

1. insoluble in \_\_\_\_\_\_\_\_ 2. usually \_\_\_\_-electrolytes 3. \_\_\_\_\_ melting point

4. react slower than inorganic compounds (smaller)

5. often require \_\_\_\_\_ activation energies for the reaction to begin

C. Formulas

1. Molecular Formula

2. Structural Formula

3. Skeletal Formula (ethane) (propane)

4. Empirical Formula

5. Isomers

* Same molecular formula, but different structural formulas

#### Galactose Glucose isomers of Pentane

C6H12O6 C6H12O6 C5H12

III. \_\_\_\_\_\_\_\_\_\_\_\_\_\_

###### A. Molecules that contain \_\_\_\_\_\_ carbon and hydrogen atoms (largest group).

###### B. \_\_\_\_\_\_\_\_\_\_\_ Series

1. Saturated Hydrocarbons (“\_\_\_\_\_\_\_\_\_\_”)

a. Contain only \_\_\_\_\_\_\_\_\_ covalent bonds between carbon atoms

b. \_\_\_\_ hybrid orbitals around the carbon atoms (\_\_\_\_\_\_\_\_\_\_\_ geometry)

skeletal formula

* Because of electron pair repulsion, carbon chains are actually “bent” so there is less atom to atom interference

c. Alkane Series (CnH2n+2)

d. \_\_\_\_\_\_\_ Groups (CnH2n+1)

* Organic molecules are classified and named according to the carbon \_\_\_\_\_\_\_\_ and also by alkyl groups
* For instance, butane (C4H10) can also be isopropane which is methyl propane (same molecular formula)

Butane methyl propane

e. Alkanes are commonly used for combustion reactions

f. \_\_\_\_\_\_\_ alkanes (CnH2n)

* Cyclo-alkanes have 2 less hydrogens per molecule
* The most common cyclo-alkanes have 5-6 carbon \_\_\_\_\_\_ because they are more stable.

2. Unsaturated Hydrocarbons (“ALKENES” & “ALKYNES”)

a. Contain at least one \_\_\_\_\_\_\_ or \_\_\_\_\_\_ covalent bond between carbons

1) \_\_\_\_\_\_\_\_\_\_ are also called the \_\_\_\_\_\_\_\_\_\_\_ series (CnH2n) and/or “\_\_\_\_\_\_\_,” containing at least one double covalent bond between carbon atoms

a) \_\_\_\_hybrid orbitals

b) unsaturated hydrocarbons are more reactive than the saturated hydrocarbons (alkanes) because the double or triple bond is less stable.

c) unsaturated hydrocarbons are often saturated by H2, HBr, Br2, HCl and Cl2

Saturation of ethylene with HBr

2) \_\_\_\_\_\_\_\_\_ are also called the \_\_\_\_\_\_\_\_\_\_\_ series (CnH2n-2) containing at least one triple covalent bond between carbons

a) \_\_\_ hybrid orbitals

b) The most reactive of the hydrocarbons

c) Acetylene is used in welding and cutting metals (high temperature flame)

b. Made by the process of \_\_\_\_\_\_\_\_\_\_\_ 🡪 long chain \_\_\_\_\_\_\_\_\_\_ are heated in the presence of a catalyst so the -C–C- bonds rupture and allow double or triple bonds to form in their place.

octane pentane propene

3. \_\_\_\_\_\_\_\_\_\_\_ Hydrocarbons (“BENZENE” Series)

a. Strong \_\_\_\_\_\_\_

b. Based on \_\_\_\_\_\_\_\_ (6 carbon \_\_\_\_\_\_)

1) A liquid which boils ~80 C

2) less reactive than alkynes/acetylenes

3) doesn’t hydrogenate (add hydrogen to unsaturated bonds) as readily as ethylenes or alkynes

c. General Formula: CnH2n-6

d. Resonance Structures 🡪 planar molecules; regular hexagonal pattern; the actual C to C bond has the same length (not “double” or “single” but in between) so the only way to represent it is via resonance structures (e.g. NO3- ion or SO2 molecule)

e. Benzene Structures

Common benzene configurations: ortho, meta, para

Napthalene is a constituent in mothballs and polymers found in car enamels

Benzene derivatives are used in gasoline and other petroleum products, cleaning agents, and many industrial intermediates

###### C. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Polymers are molecules which consist of a large number of small molecular units combined together chemically

a. The nature of polymers depends on the “\_\_\_\_\_\_\_\_\_\_” (the repeating unit within the polymer)

b. Examples

IV. IUPAC Naming

###### A. Identify the \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_

1. Number the carbon atoms sequentially to represent the \_\_\_\_\_\_\_\_\_ chain or largest “ring” – this is called the “parent” chain

* Numbering does NOT have to be horizontally arranged
* \_\_\_\_\_- (1 carbon atom), \_\_\_- (2 carbon atoms), \_\_\_\_\_\_- (3 carbon atoms)

2. Determine whether the molecule has ONLY single covalent bonds

a. All single bond(s) 🡪 \_\_\_\_\_\_\_\_ series 🡪 “-\_\_\_”

b. Double bond(s) 🡪 \_\_\_\_\_\_\_\_ /ethylene series 🡪 “-\_\_\_”

c. Triple bond(s) 🡪 alk\_\_\_\_\_\_\_\_ yne/acetylene series 🡪 “-\_\_\_”

3. Name the parent chain – this becomes the base of the molecules’ name.

###### B. Name the “\_\_\_\_\_\_\_ Groups” along the \_\_\_\_\_\_\_\_ chain

1. Determine what alkyl groups are present and how many of each.

* A single alkyl group is named as is: methyl, ethyl, propyl, etc.
* \_\_\_\_ of any alkyl group uses the prefix: “\_\_\_-“ … dimethyl, diethyl, etc.
* “\_\_\_-” refers to three of the same alkyl group, “\_\_\_\_\_\_-” refers to four of the same alkyl group, “\_\_\_\_\_-” refers to five of the same alkyl group, etc.

2. Each alkyl group will have a NUMBER corresponding to the carbon atom of the parent chain.

“2-methyl” indicates a \_\_\_\_\_\_\_ group on the number \_\_ carbon atom.

3. If the same alkyl group exists, label the numbers separated by a comma and then name the alkyl group.

* “2,3-dimethyl” indicates a methyl group on the number \_\_ and number \_\_ \_\_\_\_\_\_\_\_ atoms.
* “2-methyl, 4-ethyl” indicates a methyl group on the number \_\_ carbon atom and an ethyl group on the number \_\_ carbon atom.

Write the structural formulas for

Example 1:   2-methyl pentane.

Example 2:  2,3-dimethyl butane.

Example 3:  2,2-dimethyl butane.

Example 4:  2-methyl 3-ethyl hexane.

Note:   Normally, the name of an organic molecule lists the \_\_\_\_\_\_\_ numbered alkyl group first and then goes \_\_\_\_\_\_\_\_\_\_\_\_. Some naming systems alphabetize the name by alkyl group (i.e. 3-ethyl 2-methyl hexane).

V. \_\_\_\_\_\_\_\_\_\_\_ Containing Organic Molecules

* The next most abundant organic molecules after hydrocarbons
* Often named after their hydrocarbon “roots”
* \_\_\_\_\_\_\_\_\_\_\_ Groups

1. A particular arrangement of a few atoms which give characteristic \_\_\_\_\_\_\_\_\_\_\_\_ to an organic molecule

2. Organic molecules can often be composed of 1 or more “functional groups” attached to a \_\_\_\_\_\_\_\_\_\_\_ backbone or \_\_\_\_\_\_\_\_\_\_.

3. “\_\_\_” will represent a carbon based unit.

###### A. \_\_\_\_\_\_\_\_\_\_\_\_\_

1. Functional Group: R—OH

2. Characteristics

a. not “bases” … even though it contains an “OH” (hydroxyl) group … does NOT \_\_\_\_\_\_\_\_\_\_\_\_\_ in an aqueous solution

b. \_\_\_\_-electrolytes

c. does exhibit \_\_\_\_\_\_\_\_\_ bonding (strengthens inTERmolecular bonds)

3. Classes of Alcohols

a. \_\_\_\_\_\_\_\_ / Terminal –OH is attached to the end/terminal carbon atom

2) Naming depends on the number of carbon atoms … change the ending to “-\_\_\_”

\_\_\_\_\_\_\_ol, \_\_\_anol, \_\_\_\_anol, \_\_\_\_anol, pentanol, etc.

b. \_\_\_\_\_\_\_\_\_\_\_\_ –OH is attached to a non-terminal carbon atom

2) Naming depends on the position of the “-OH” group, the number of the carbon atom, and changing the ending to “-ol”

2-propanol

c. \_\_\_\_\_\_\_\_\_\_ –OH is attached to a carbon atom that is bonded to TWO other carbon atoms (three carbon atoms total … “\_\_\_\_\_\_”)

2) Naming depends on the position of the “-OH” group, the number of the carbon atom, and changing the ending to “-ol”

* The following alcohol can be named more than one way:

d. Diols and Triols

1) Alcohols often contain more than one –OH group is attached to a carbon atom that is bonded to TWO other carbon atoms (three carbon atoms total … “tert”)

2) Naming depends on the position of the “-OH” group, the number of the carbon atom, and changing the ending to “-ol”

###### B. \_\_\_\_\_\_\_\_\_

1. Functional Group: R—O— R’

2. Characteristics - exhibit little to no Hydrogen bonding; every ether has one isomeric alcohol; they are common linkages in carbohydrates and lignin; formerly used as \_\_\_\_\_\_\_\_\_\_

3. Naming Ethers

a. recognize the ether functional group

b. name the alkyl group on each side of the oxygen atom

* Ether or sweet oil was discovered by Spanish chemist, Raymundus Lullius in 1275.
* In 1540 German Scientist, Valerius Cordus described how to synthesize it and Swiss physician, Paracelsus discovered the medicinal uses of ether.
* MTBE gasoline additive

###### C. Aldehydes

1. Functional Group:

2. Characteristics 🡪 -C=O is highly polar … relatively unstable molecules; are used in \_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_, and \_\_\_\_\_\_ (fabric); functional group is moderately reactive and can be further oxidized to form a carboxyl group (no hydrogen atom); produced from terminal alcohols.

3. Naming Aldehydes

a. Write it as -\_\_\_\_\_ - never as -COH, because that looks like an alcohol

b. The names of aldehydes end in \_\_\_\_.

Formaldehyde (carcinogenic) was commonly used to preserve animals, plants, etc.

###### D. Organic Acids

1. Functional Group:

2. Characteristics 🡪 Do NOT \_\_\_\_\_\_ in water (non-electrolytes); Aldehydes easily oxidize to form the carboxylic acid group; used in making plastics, wood glue, synthetic fibers and fabrics, descaling agents; (along with esters) are main ingredients in aspirin, soaps, detergents; strong, rancid \_\_\_\_\_\_.

3. Naming Organic Acids

a. Organic acids usually are given a \_\_\_\_\_\_\_ name because they are abundantly used in industry

b. The IUPAC naming system identifies the carbon chain

c. The names of organic acids end in -\_\_\_\_ acid.

E. Ketones

1. Functional Group:

* a type of molecule that features one carbonyl group (C=O) bonded to two other carbon atom

2. Characteristics 🡪 Non-terminal alcohols (-OH) are oxidized to form ketones; Every ketone has at least one isomeric aldehyde; produced on massive scales in industry as solvents, polymer precursors, and pharmaceuticals; the brain, in particular, relies heavily on ketone bodies as a substrate for [lipid](http://en.wikipedia.org/wiki/Lipid) synthesis and for energy during times of reduced food intake.

3. Naming Ketones

a. The IUPAC naming system identifies the carbon chain. Ketones are named by changing the suffix -e of the parent alkane to -\_\_\_\_.

b. The most important ketones, e.g. acetone and benzophenone.

c. The position of the carbonyl group is usually denoted by a number.

Common solvent for cleaning purposes in the laboratory. active ingredient in nail polish remover and as paint thinner and sanitary cleaner/nail polish remover base.

2 butanone or methyl ethyl ketone CH3C(O)CH2CH3

Solvent, found in coatings and in vinyl films use in the manufacture of plastics, textiles, in the production of paraffin wax, and in household products such as laquer, varnishes, paint remover, a denaturing agent for denatured alcohol, glues, and as a cleaning agent. Butanone is also used in dry erase markers as the solvent of the erasable dye.

###### F. \_\_\_\_\_\_\_\_\_\_

1. Functional Group:

* the product of the reaction between an organic acid and an alcohol

2. Characteristics 🡪 General formula written as: \_\_\_\_\_\_\_\_\_\_; pleasant \_\_\_\_\_\_, less soluble in water than alcohols or organic acids; Industrial solvents; used in manufacturing \_\_\_\_\_\_\_\_ (plexiglas, dacron); commonly used in fragrances and artificial flavoring in foods. Found in “essential oils” (An oil is "essential" in the sense that it carries a distinctive scent, or essence, of the plant.) and pheromones; esters (along with organic acids) are main ingredients in aspirin, soaps, detergents; many common fragrances contain multiple esters (pineapple, cherry, pear, grape, banana, apple).

3. Naming Esters

a. Ester names are derived from the names of the parent \_\_\_\_\_\_\_\_\_ and the carboxylic \_\_\_\_\_\_ followed by the suffix -\_\_\_\_\_\_.

Table of Common Esters and their Derivations (give a few examples)

VI. Organic Processes

###### A. \_\_\_\_\_\_\_\_\_\_\_\_

1. One element replaces another. Often, organic substitution occurs with \_\_\_\_\_\_\_\_

2. With the exception of iodine, halogens are more \_\_\_\_\_\_\_\_\_\_\_\_\_ than carbon.

a. The halogen has a negative polarity while the carbon based chain has a positive polarity.

b. Normally, the H of a saturated hydrocarbon is replaced by the halogen

c. This process is called “\_\_\_\_\_\_\_\_\_\_\_\_\_\_” or halogen substitution.

###### B. \_\_\_\_\_\_\_\_\_\_\_

1. Adding one or more elements to an \_\_\_\_\_\_\_\_\_\_\_\_\_ hydrocarbon (alkenes or alkynes).

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

a. Hydrogen is often the element that replaces the double or triple bond of the organic molecule.

b. Some margarine is made by hydrogenating carbon-carbon double bonds in animal or vegetable fats and oils. You can recognize the presence of this in foods because the ingredients list will include words showing that it contains "hydrogenated vegetable oils" or "hydrogenated fats".

3. There are some probable health risks from eating hydrogenated fats or oils.

a. The relatively high temperatures used in the hydrogenation process flip some of the carbon-carbon double bonds into the "\_\_\_\_\_" form.

b. If these particular bonds aren't hydrogenated during the process, they will still be present in the final margarine in molecules of trans \_\_\_\_\_.

c. The consumption of trans fats has been shown to \_\_\_\_\_\_\_\_\_\_\_ cholesterol levels (particularly of the more harmful \_\_\_\_\_\_ form) - leading to an increased risk of heart disease.

###### C. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. "Cracking" breaks \_\_\_\_\_\_\_\_ molecules into smaller ones. This can be done with a thermic or \_\_\_\_\_\_\_\_\_ method.

2. Cracking processes allow the production of liquified petroleum gas (\_\_\_\_\_), gasoline products, jet \_\_\_\_\_, and \_\_\_\_\_\_\_ fuels.

exhibit little Hydrogen bonding; every ether has one isomeric alcohol; common linkages in carbohydrates & lignin; formerly used as anesthetics

3. Break down complex “\_\_\_\_\_\_\_\_” (long chain alkanes/waxes) to smaller “\_\_\_\_\_\_\_\_” (possess a double bond … alkenes)

###### D. \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Conversion of carbohydrates or organic acids

2. Anaerobic Respiration is biochemical fermentation

Glucose → Energy (ATP) + Ethanol + Carbon dioxide (CO2)  
Glucose → Energy (ATP) + Lactic acid

a. production of energy

b. The process of anaerobic respiration yields less energy than aerobic respiration.

3. A metabolic process 🡪 electrons released (oxidation) from nutrients are transferred to molecules obtained from the breakdown of those same nutrients.

a. cider, winemaking, brewing beer (alcohol based)

b. flavoring in foods and tea leaves (lactic acid based) … sauerkraut, dry sausages, kimchi, yogurt or vinegar for use in pickling foods.

4. In industry, fermentation is the breakdown and re-assembly of biochemicals for industry. There are 5 major groups of commercially important fermentation reactions (name a few):

###### E. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Exothermic chemical reaction between a fuel and an oxidant (oxidizing element)

2. Organic combustion usually works with a hydrocarbon. The general form of a combustion reaction is:

3. Common hydrocarbons used in combustion

a. methane (“natural gas”), ethane, propane (grills), butane (lighters), octane (gasolines)

b. cyclic hydrocarbons yield a lot of energy (heat) … 485 kcal/mole (cyclopropane) to 1400 kcal/mole (cyclodecane)

###### F. Esterification

1. Production of esters from an alcohol and organic acid

2. See “Esters” in previous section (oxygen containing organic molecules)

###### G. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. (“\_\_\_\_\_ making”) is the [hydrolysis](http://en.wikipedia.org/wiki/Hydrolysis) of an [\_\_\_\_\_](http://en.wikipedia.org/wiki/Ester) under [basic](http://en.wikipedia.org/wiki/Base_(chemistry)) (alkaline) conditions to form an [alcohol](http://en.wikipedia.org/wiki/Alcohol) and the salt of a [carboxylic acid](http://en.wikipedia.org/wiki/Carboxylic_acid) ([carboxylates](http://en.wikipedia.org/wiki/Carboxylate)).

2. Commonly used to refer to the reaction of a metallic alkali ([base](http://en.wikipedia.org/wiki/Base_(chemistry))) with a [fat](http://en.wikipedia.org/wiki/Fat) or [oil](http://en.wikipedia.org/wiki/Oil) to form [soap](http://en.wikipedia.org/wiki/Soap). [When a vegetable oil or animal fat is mixed with a strong alkali. The products of the reaction are two: soap and glycerin.]

a. Natural soaps are sodium or potassium salts of fatty acids, originally made by boiling lard or other animal fat together with lye or potash (potassium hydroxide).

b. Hydrolysis of the fats and oils yields glycerol and crude soap.