Dear Chemistry Two student,

We would like to congratulate you on your choice to enroll in Chemistry 2. As you may already know Chem. 2 is an advanced college level course in a subject that is a difficult one for many people. We admire your dedication and your choice to challenge yourself personally and academically. You will soon discover what it means to enroll in a college level science course, as you undergo the transition from chemistry student, to student chemist (or as we like to say from a chem Oneder to a chem Doer). This means you will take on the role of being truly in charge of your own learning as your instructor steps back and takes on the role of facilitator. The first part of this transition will involve completing a few review assignments over the summer to ensure that you are properly prepared to keep up with the class when we return.

By having you complete this review during the more relaxed pace of summer, it will allow us to move at a slightly less-frenetic pace as we cover the extensive amount of content required to prepare you for the AP or IB exam in chemistry.

As you complete the assignments, indicate any questions you have over the material, as there will be opportunities to ask those questions during the first few days of class. If your question requires more immediate attention, feel free to send us an email and we will respond as quickly as possible.

Once again, we appreciate your commitment to excellence and we are looking forward to a molevelous year!

Sincerely, your chemistry spirit animal and personal hero

Jerred Bardwell

Naming Compounds and Writing Formulas

Elements occur in constant whole number ratios in a compound (Law of Definite proportions). In a chemical formula symbols and subscripts are used to describe this ratio. For molecules the chemical (molecular) formula shows the **actual** number of atoms of each element in the compound. In an ionic compound, the formula shows the **lowest whole number ratio** of elements in the ionic crystal. This ratio is called a **formula unit.**

Naming Ionic Compounds (Any substance which contains a metal and a nonmetal, or any polyatomic ions).
Simply name the two ions, positive ion first (the positive ion is always written first as well). Positive monatomic (one type of element) ions have the same name as the element. Na^+ is sodium ion, Al^{3+} is aluminum ion. Negative monatomic ions end in **-ide**. Cl^- is chloride ion, O^{2-} is oxide ion. Negative polyatomic ions end in **-ate** or **-ite**. There is not really any hard and fast rule which will allow you to determine if a polyatomic ion is -ate or -ite (which is why you have to memorize them), but there is one helpful shortcut.

The **most common** form of a polyatomic ion formed from a nonmetal combined with oxygen ends in -ate. ClO_3^- **chlorate** is the most common form of polatomic ion formed from chlorine and oxygen. When the polyatomic ion has one less oxygen than the most common form, the ion ends in -ite. ClO_2^- is **chlorite**. If the ion has two less O's than the most common form then the prefix **hypo-** is used. ClO^- is **hypo**chlorite (notice that the ending is still -ite). If the ion has one **more** O than the most common form then the -ate ending is used, but with the prefix **per-** ClO_4^- is **per**chlorate.

When writing formulas, use appropriate subscripts so the the total number of positive and negative charges cancel out and the compound is neutral.

Now we are ready to write some formulas and name some ionic compounds.

Examples:

KBr - since this has a metal, K and a nonmetal Br, we name it as an ionic compound. So we name the positive ion - potassium and the negative ion with the ending changed to -ide, bromide = potassium bromide .

Calcium chloride - again a metal and a nonmetal so it's ionic. Calcium would form an ion with a 2+ charge and chloride would be 1-,

$Ca^{2+}Cl^{-}$, in order for the compound to be neutral, there would have to be 2 Cl^{-} for every 1 Ca^{2+} ion, so the formula would be **$CaCl_2$** .

Na_2CO_3 - In this compound there are two ways to identify it as ionic. It has a metal and it has a polyatomic ion. So we name the ions, positive ion first. **sodium carbonate**

Magnesium phosphate - magnesium - Mg^{2+}, phosphate - PO_4^{3-} . In order for the compound to be neutral we have to find the least common multple between our two charges, 2 and 3 . The LCM is 6. 2 goes into six 3 times so Mg_3 and 3 goes into 6 two times so $(PO_4)_2$. 3 x +2 = +6 and 2 X -3 = -6. 6+ (-6) = 0, so the compound is neutral and therefore our formula is $Mg_3(PO_4)_2$

Note: unlike the previous examples, if we need more than 1 polyatomic ion, it must be surrounded with parentheses before you add the subscript. Also notice that if the subscript is 1 we do not write it.

If the positive ion has more than one possible oxidation number, then when we write the name we must indicate which oxidation state it is. This is done by writing a roman numeral in parentheses which is equal to the positive charge.

Cu_2O - copper(I) oxide Fe_2O_3 - iron(III) oxide

Note: The roman numerals are used only when writing the name, never when writing the formula!

<u>Naming Molecular Compounds</u> (2 or more nonmetals)

Simply use the appropriate prefix before the name of the element. The most electronegative element is written second and ends in -ide. Do not write the prefix <u>mono</u> for the first element, but you should for the second. The preifixes are : 1 - mono; 2 - di; 3 - tri; 4 - tetra; 5 - penta; 6 - hexa; 7 - hepta; 8 - octa; 9 - nona; and 10 - deca.

Examples: CO_2 - carbon dioxide   CO - carbon monoxide

PCl_5 - phosphorus pentachloride N_2O_5 - dinitrogen pen<u>to</u>xide

Note: Be sure to drop the last vowel of the prefix if there would be any a-o, o-o, or a-a combinations (pentoxide, not pentaoxide).

Practice examples:

Cl_2O	dichlorine monoxide
tetraiodine nonoxide	I_4O_9
SF_6	sulfur hexafluoride

<u>Naming Hydrates</u>

Hydrates are crystalline compounds which attract and hold water molecules. The water is called the **water of hydration** and can be removed (evaporated) by heating. After water is removed the crystal is said to be **anhydrous**. To name hydrates simply name the compound (usually ionic) and then indicate the number of water molecules by using the same prefixes as in molecular compounds.

Examples: $CuSO_4 \cdot 5\ H_2O$ copper(II) sulfate pentahydrate

Practice example: sodium carbonate heptahydrate $Na_2CO_3 \cdot 7\ H_2O$

Naming Arrhenius Acids

Arrhenius acids are compounds which lose H^+ ions in H_2O. The general form for an acid is HA where H is hydrogen and A is either a monatomic or polyatomic anion. Here are the rules for naming acids.

1. If the anion part normally ends in **-ide** (binary acid), then the acid name begins with the prefix **hydro** and ends with **-ic.**
   Example: HCl is hydrochloric acid

2. If the anion part ends in **-ate** (polyatomic) then NO hydro is used and the ending is -ic.
   Example: HNO_3 is nitr**ic** acid (notice there is no hydro).

3. If the anion part normally ends in **-ite** no hydro is used and the ending is **-ous**. Example: HNO_2 is nitr**ous** acid

4. To write formulas for acids just use the number of H's equal to the negative charge of the anion (since each H is +1).
   Example: carbonic acid - no hydro is used so the anion must be polyatomic. The acid name ends in -ic so the anion must end in -ate, i.e. carbonate. Since carbonate is CO_3^{2-} two H's are necessary and the formula is H_2CO_3.

Note: For a couple of elements only part, or even none, of the element ending is dropped before adding the acid ending. For example H_2SO_4 is not sulfic acid it is sulfuric acid. H_3PO_4 is phosphoric acid, not phosphic acid.

Organic Chemistry

There are approximately 3 million organic compounds (more than 90% of all known compounds) because:

- Carbon atoms can bond together to form long chains
- Organic compounds commonly show *isomerism*

3 Series of Hydrocarbons (molecules of C and H)

Saturated – all bonds between carbon atoms are single bonds.

Unsaturated – one or more double or triple bonds.

Aromatic – have structures built around **benzene**.

Properties of Hydrocarbons

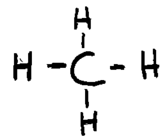
- Most common hydrocarbons are gases (C1 – C3) or liquids at ordinary temperatures and pressures.

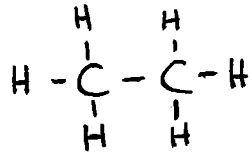
- Boiling point increases with increasing size (what type of IMF?). Very heavy organic molecules are soft, waxy solids.

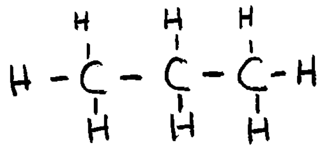
- Since hydrocarbons are non-polar they are virtually ________________ in water. (You fill in the blank)

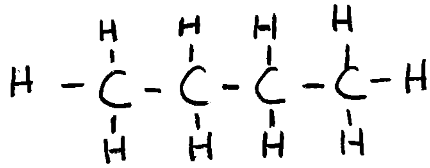
- A *homologous series* consists of the same types of organic molecules which differ only by the number of CH_2 groups within the molecule (many examples to follow).

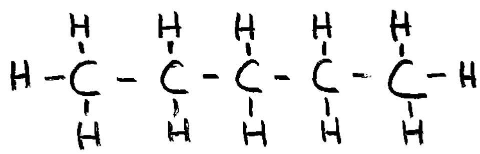
Saturated Hydrocarbons (General formula = C_nH_{2n+2})

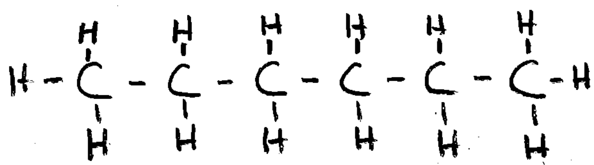
Methane CH_4  ← (structural formula)

Ethane C_2H_6 

Propane C_3H_8 

Butane C_4H_{10} 

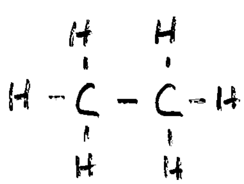
Pentane C_5H_{12} 

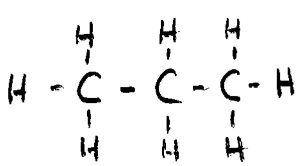
Hexane C_6H_{14} 

> Note that each end carbon bonds to 3 hydrogens.
>
> Other carbons have 2 bonds to hydrogen

Heptane C_7H_{16}, Octane C_8H_{18}, Nonane C_9H_{20}, Decane $C_{10}H_{22}$

It is also acceptable to write the structural formula without showing all of the C – H bonds. For example:

Ethane  or CH_3-CH_3 or CH_3CH_3

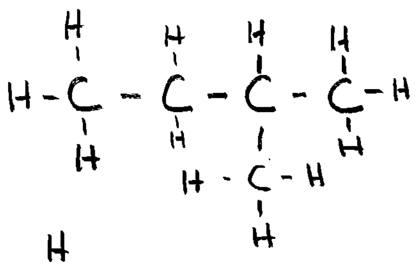
Propane  or $CH_3-CH_2-CH_3$ or $CH_3CH_2CH_3$

Naming *Alkanes* (saturated hydrocarbons)

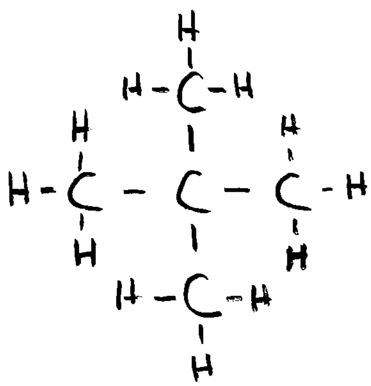
The name begins with a prefix which denotes an *alkyl group* (branced chain) or *functional group* (group where the element attached to a carbon is not C or H). Examples: meth**yl** $-CH_3$; ethyl $-CH_2CH_3$; propyl $-CH_2CH_2CH_3$
Functional groups: chloro -Cl ; iodo -I ; ol (alcohol) -OH

Next comes the family name which depends on the number of carbons in the **LONGEST chain!** Methane, ethane, etc.

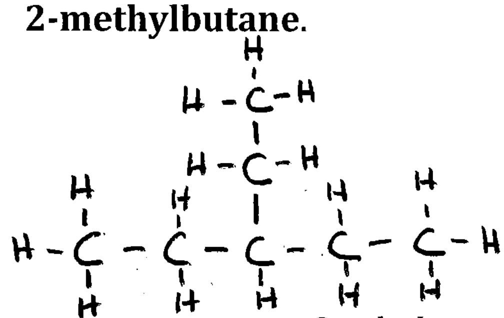
A number is used to show the carbon atom(s) in the main chain at which branching occurs or functional groups are attached. Here are some examples:



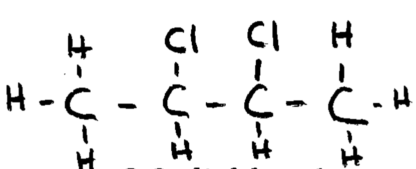
The main chain has 4 carbons so this is **butane**. The methyl group ($-CH_3$) is attached to the 2[nd] carbon in the chain, so this is **2-methylbutane**.



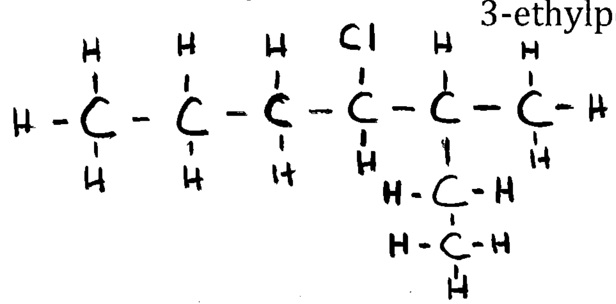
2,2-dimethylpropane



3-ethylpentane



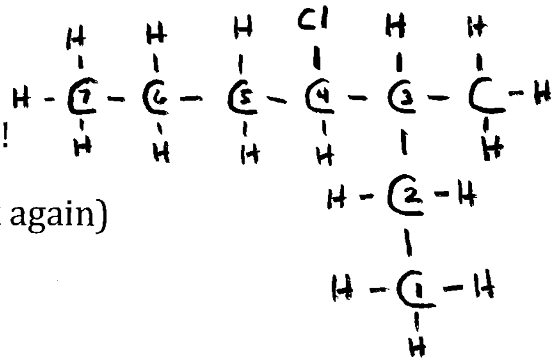
2,3-dichlorobutane



3-chloro-2-ethylhexane, right?

NOT!!

(look again)

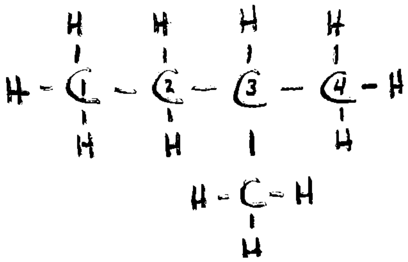


4-chloro-3-methylheptane

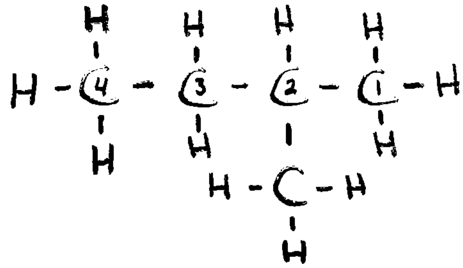
Always use the longest possible main chain!!!!

Other Things to Watch For:

- Always number the main chain so branches and functional groups are at the lowest number possible:

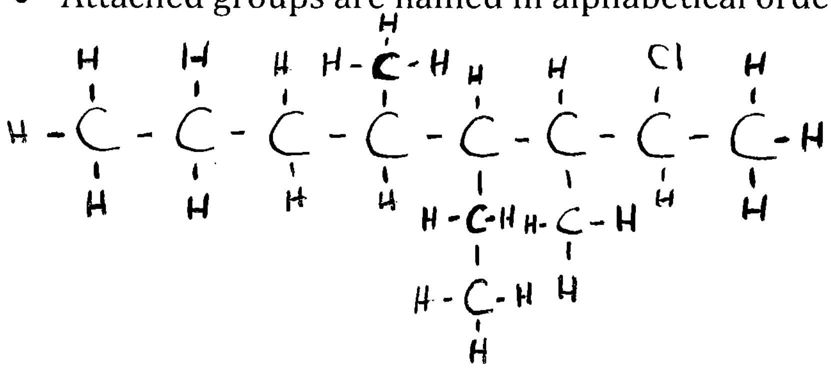


3-methylbutane? NO!



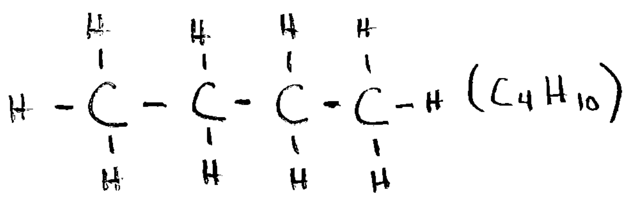
2-methylbutane? Yes.

- Attached groups are named in alphabetical order

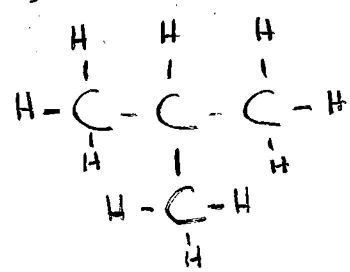


2-chloro-4-ethyl-3,5-dimethyloctane (note the prefix does not count)

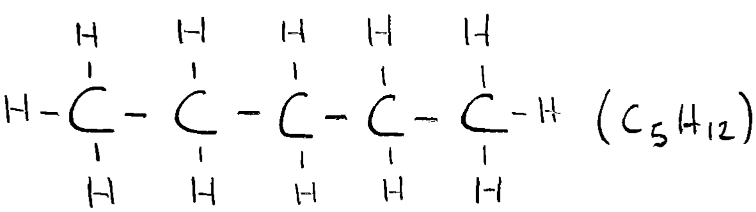
Isomers (same formula, different structure)



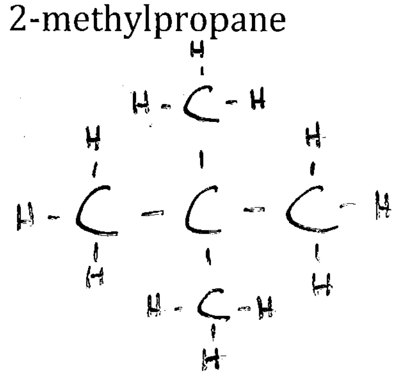
butane is an isomer of



2-methylpropane

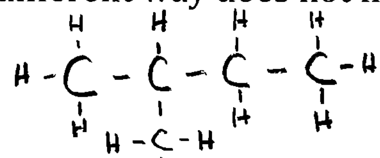


pentane is an isomer of

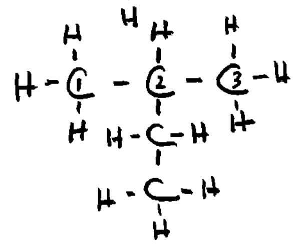


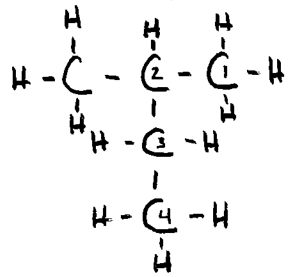
2,2-dimethylpropane

<u>BE CAREFUL</u>: Just writing a structure a different way does not make it an isomer! For example: 2-methylbutane is an isomer of pentane.

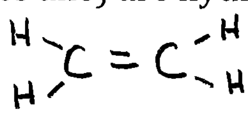


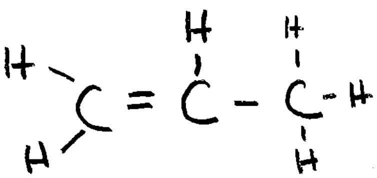
One might also think that this structure is *2-ethylpropane* and is therefore a different isomer. Numbered properly; however (always use the longest chain), one realizes this is actually just 2-methylbutane written a different way.





<u>Unsaturated Hydrocarbons</u>

- *Alkenes* (ene replaces ane) are hydrocarbons with double bonds. This is eth**<u>ene</u>**  (also known as ethylene)



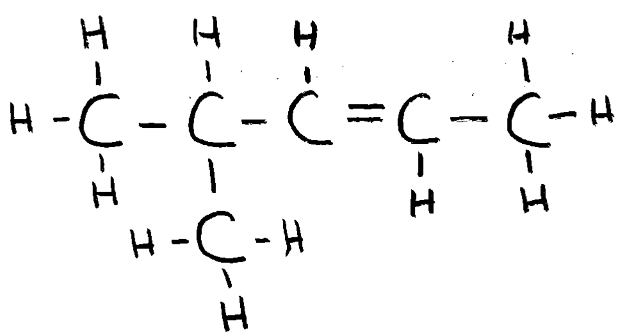
propene

$$CH_3-CH_2-CH=CH_2$$

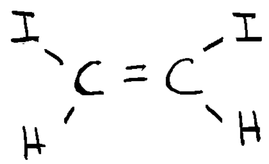
1 – butene

Alkenes are always named so that the double bond is at the lowest possible position. For example:
would be named

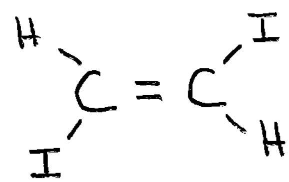
4-methyl-2-pentene



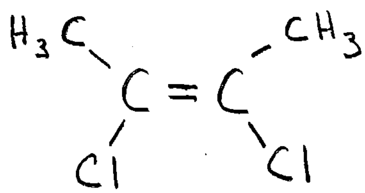
<u>Geometric Isomers</u> (alkenes/cycloalkanes only): When branches or functional froups are on the same side of the double bond, the isomer is called ***cis***. If they are on opposite sides the isomer is called ***trans***. Examples:



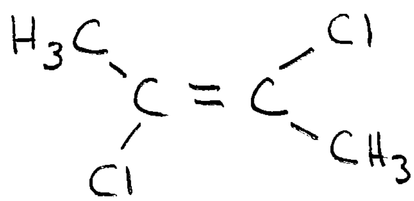
diiodo-cis-ethene



diiodo-trans-ethene



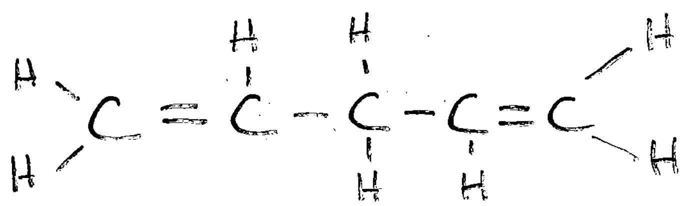
2,3-dichloro-cis-2-butene



2,3-dichloro-trans-2-butene

N. b. - If a compound has more than one double bond, identify the position of each one and use the appropriate prefix before ene.

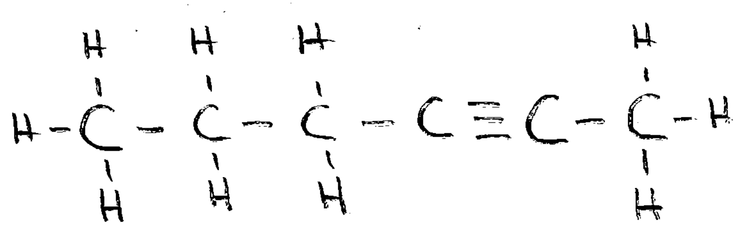
For example:



1,4-pentadiene

- *Alkynes* (yne replaces ane) are hydrocarbons which have triple bonds

ethyne (also known as acetylene)



2-hexyne

Summary Sheet - Functional Groups (1)

"Master Organic Chemistry"
masterorganicchemistry.com
August 2012 Version 1.1

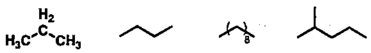
Note - this sheet is not meant to be comprehensive. Your course may provide additional material, or may not cover some of the reactions shown here. Your course instructor is the final authority.

What Are Functional Groups?

Functional groups are collections of atoms that have a common pattern of chemical reactivity

Alkane —C— *a hydrocarbon with no multiple bonds is an alkane*

Suffix: "-ane". As a substituent: "alkyl"
Examples:

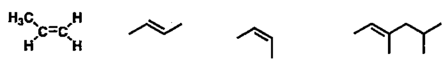


Propane | Butane | Decane | 2-methylpentane

Characteristics: nonpolar
Geometry: tetrahedral (sp^3 *hybridized*)
Reactivity: ***free radical reactions** (e.g. free radical chlorination or bromination)*

Alkene C=C *a hydrocarbon with at least one C–C double bond (π bond) is an alkene*

Suffix: "-ene". As a substituent: "alkenyl"
Examples:



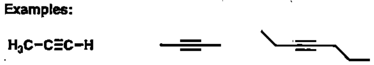
Propene | *trans*-2-butene [or (*E*)-2-butene] | *cis*-2-butene [or (*Z*)-2-butene] | (*E*)-3,5-dimethylhex-2-ene

Characteristics: nonpolar. Molecule cannot rotate along double bond.
Geometry: trigonal planar (sp^2 hybridized)
Reactivity: *undergo **addition** reactions, as well as **oxidative cleavage***
Stability increases with increasing # of carbons attached

Alkyne —C≡C— *a hydrocarbon with at least one C–C triple bond (π bond) is an alkyne*

Suffix: "-yne". As a substituent: "alkynyl"

Examples:

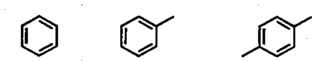


H_3C–C≡C–H Propyne a *terminal* alkyne | 2-butyne | 3-heptyne

Alkynes with a C–H bond are called "terminal" alkynes
Geometry: linear (*sp* hybridized)
Characteristics: non polar
Reactivity: ***addition** reactions*
***oxidative cleavage** reactions*
***acid-base** reactions (terminal alkynes are unusually acidic)*

Benzene ring *A six-membered ring containing 3 alternating double bonds is a benzene ring*

Suffix: "benzene". As a substituent: "phenyl"
Examples:



Benzene | Methylbenzene (toluene) | 1,4-dimethylbenzene (*para*-dimethylbenzene)

Reactivity: ***substitution** reactions (e.g. electrophilic aromatic substitution or nucleophilic aromatic substitution)*
Less reactive than normal alkenes due to aromatic stability

Alcohol $R–\ddot{O}^{\delta-}–H^{\delta+}$ *The OH group is an alcohol [unless OH is attached to C=O, in which case it's a carboxylic acid (below)]*

Suffix: "-ol". As a substituent: "hydroxy"
Examples:

Methanol | Ethanol a *primary* alcohol | 2-propanol ("isopropanol") a *secondary* alcohol | 2-methyl-2-propanol (*t*-butanol) a *tertiary* alcohol

Characteristics: polar (O-H group participates in hydrogen bonding)
Reactivity: ***acid-base** reactions (can act as acids or bases)*
***substitution** reactions (can act as nucleophiles)*
***oxidation** reactions (primary and secondary alcohols (and methanol) can be oxidized to aldehydes, ketones, or carboxylic acids, depending on structure and reagent used)*

Ether $R–\ddot{O}^{\delta-}–R^{\delta+}$ *An oxygen flanked by two carbons is an ether*

As a substituent: "alkoxy"

Examples:

Dimethyl ether | Ethyl methyl ether (or "methoxyethane") | Methyl phenyl ether (or "methoxybenzene", or "anisole") | Tetrahydrofuran (THF) a cyclic ether

Characteristics: borderline between nonpolar and polar (due to dipole-dipole)
Reactivity: ***acid-base** reactions (oxygen can act as a very weak base*

Alkyl halide $R^{\delta+}–F^{\delta-}$ $R^{\delta+}–Cl^{\delta-}$ $R^{\delta+}–Br^{\delta-}$ $R^{\delta+}–I^{\delta-}$ *An alkyl group attached to a halogen is an alkyl halide*

Suffix: "-ane". As a substituent: "haloalkyl"
Examples:

Iodomethane (methyl iodide) | Fluoroethane (ethyl fluoride) a *primary* alkyl halide | 2-chloropropane (isopropyl chloride) a *secondary* alkyl halide | 2-methyl-2-bromopropane (*t*-butyl bromide) a *tertiary* alkyl halide

Characteristics: generally considered non polar (but more polar than alkanes)
Reactivity: ***substitution** reactions (Cl, Br, I can be good leaving groups)*
***elimination** reactions (Cl, Br, I can be good leaving groups)*

Amine $R–\ddot{N}^{\delta-}(H)–H^{\delta+}$ *A nitrogen attached to simple carbon or hydrogen atoms is an amine*

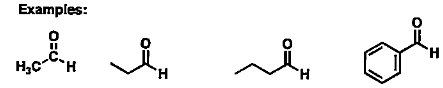
Suffix: "-ine". As a substituent: "amino"
Examples:

Methylamine | Ethylamine a *primary* amine | Dimethylamine a *secondary* amine | Triethylamine a *tertiary* amine

Characteristics: polar (N-H group participates in hydrogen bonding, although not as much as a hydroxy group
Reactivity: ***acid-base** reactions (tend to act as bases)*
***substitution** reactions (can act as nucleophiles)*

Aldehyde $R–C^{\delta+}(=O^{\delta-})–H$ *A carbonyl (C=O) attached to a hydrogen and another carbon is an aldehyde*

Suffix: "-al" (if attached to ring: carbaldehyde) As a substituent: "oxo"
Examples:

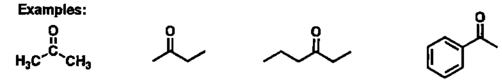


Ethanal | Propanal | Butanal | Benzaldehyde

Characteristics: the C=O bond is somewhat polar
Reactivity: ***addition** reactions (the carbonyl carbon reacts easily with nucleophiles)*

Ketone $R–C^{\delta+}(=O^{\delta-})–R$ *A carbonyl (C=O) flanked by two carbons is a ketone*

Suffix: "-one". As a substituent: "oxo"
Examples:

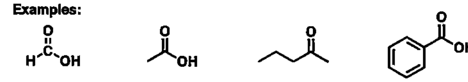


2-propanone ("acetone") | 2-butanone ("methyl ethyl ketone") | 3-hexanone | phenyl methyl ketone ("acetophenone")

Characteristics: the C=O bond is somewhat polar (less so than O-H however)
Reactivity: ***addition** reactions (the carbonyl carbon reacts easily with nucleophiles)*
***acid-base** reactions (carbons adjacent to the ketone can be deprotonated to give enolates)*

Carboxylic acid $R–C^{\delta+}(=O^{\delta-})–O^{\delta-}–H^{\delta+}$ *A carbonyl (C=O) adjacent to a hydroxyl (OH) and an R group is a carboxylic acid*

Suffix: "-oic acid"
Examples:

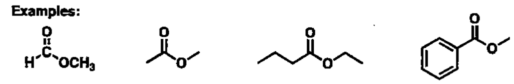


Methanoic acid ("formic acid") | Ethanoic acid ("acetic acid") | Butanoic acid | benzoic acid

Reactivity: ***acid-base** reactions (the O–H is acidic)*
***acyl substitution** reactions (can replace OH with other groups under acidic conditions)*

Ester $R–C^{\delta+}(=O^{\delta-})–\ddot{O}–R$ *A carbonyl (C=O) adjacent to an alkoxy (OR) and an R group is an ester*

Suffix: "-oate"
Examples:



Methyl methanoate | Methyl ethanoate | Ethyl butanoate | Methyl benzoate

Reactivity: ***acyl substitution** reactions (can replace OR with other functional groups under acidic conditions)*
***addition** reactions (the carbonyl carbon reacts easily with nucleophiles)*

Omissions, Mistakes, Suggestions?

james@masterorganicchemistry.com

Common Laboratory Equipment