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# Organic Chemistry lesson 1

### What does Organic mean?

Compounds in which carbon is the principle element

### Why can carbon form a variety of compounds?

Form 4 bonds

Form chains, sheets, rings, spheres and tubes

Form single, double and triple bonds

### Aliphatic (open chain) Hydrocarbons: Only C and H

### Uses

Mainly fossil fuels (methane, propane, octane)

3 kinds (alkanes, alkenes, alkynes)

### Alkanes

Carbon are bonded to other carbon by single bonds, therefore – maximum number of hydrogen atoms (aka SATURAYED like the fats)

### Drawing Alkanes:

C3H8

Full structural formula

CH3, CH2, CH3 -> Condensed structural formula

Skeletal formula: ^

\*Not used unless specified

C5H12

## Homologous Series

### What is it?

A homologous series is one in which all the members have the same general formula.

### Features:

Neighboring member differ by -CH2-

Similar chemical properties

Gradation in their physical properties

Graduate change

Alkanes are an example of homologous series

## Naming (IUPAC)

Suffix -ane

Prefix indicates number of carbon atoms in the longest chain in the molecule

General Formula = C(n) H(2n+2)

|  |  |  |  |
| --- | --- | --- | --- |
| # carbon | Prefix | IUPAC name | Molecular Formula |
| 1 | Meth- | Methane | CH4 |
| 2 | Eth- | Ethane | C2H6 |
| 3 | Prop- | Propane | C3H8 |
| 4 | But- | Butane | C4H10 |
| 5 | Pent- | Pentane | C5H12 |
| 6 | Hex- | Hexane | C6H14 |
| 7 | Hept- | Heptane | C7H16 |
| 8 | Oct- | Octane | C8H18 |
| 9 | Non- | Nontane | C9H20 |
| 10 | Dec- | Dectane | C10H22 |

### Empirical formula

Represents formula of compound in simplest whole # ratios

### Drawing/naming Branched alkanes

1. Identify longest chain and assign base name
2. Side chains are called “alkyl” groups (substituents) Find prefix and change “ane” to “yl” (ie: methyl, ethyl)
3. # each C (start at the end which is closest to a substituent)
4. Name each substituent and where it is located
5. List in alphabetical order when more than one substituent

### Example

Base: heptane

Side chain: 2-methyl, 4-ethyl

Name is 4-ethyl-2-methylheptane

### Draw

2-methylpentane

### Cycloalkanes

1. Identify ring
2. Number the carbons
3. Se “cyclo” as a prefix (ie. Cyclohexane)
4. Name substituent group and location (note: if you have 2 different groups, the one that comes first alphabetically gets the smaller #)

Examples (naming and drawing)

cyclopropane

cyclobutene

1,2-dimethylcyclopentane

Draw: 1-methyl-2-propylcyclohexane

## Properties of hydrocarbons (alkanes, alkenes and alkynes)

Because C-H bonds are relatively non-polar (EN diff = 0.4)

They have/are:

\*low solubility in polar solvents (like water) … high solubility in non-polar solvents -LIKES DISSOLVE LIKES!! (as they get longer, they become more non-polar)

\*good solvents for non-polar compounds

Because they have only London forces and intermolecular forces they have:

\*low mp/bp (so many are gases) … but as they get longer they are more likely to be solids and have higher bp (more electrons means stronger London forces remember?)

### Structural Isomers

Compounds with the same molecular formula, but different arrangements of their atoms

Example

Butane:

CCCC

2-methylpropane:

CCC-CH3

# Organic Chemistry Lesson 2

Condensed: CH3CH2CH2CH3

CH3(CH2)2CH3

CH3-CH2-CH2-CH3

## Reaction of Alkanes

* Alkanes are very unreactive (“Paraffins” – little activity)
* Reasons
  + Carbon-Carbon bonds are relatively strong (average bond enthalpy = 346kJ/mol)
  + Carbon-hydrogen bonds are relatively strong (average bond enthalpy = 414kJ/mol)
  + Inability to expand their octet

### Combustion Reactions

Complete Combustion reaction:

C3H6 + 5O2 -> 3CO2 + 4H2O

Incomplete Combustion reactions:

2C3H8 + 7O2 -> 6CO + 8H2O

Propane

### Substitution reactions with Halogens

* Vigorous with F2 (no catalyst needed)
* Cl2 and Br2 require the addition of UV light – catalyst
* + -UV light-> +
  + Name of produce: 1-brommoethane
  + Result -> a Halogenalkane
* + 2 -UV light-> + 2
  + 1,2-dibromethane

## Reaction Mechanism

* Reaction Mechanism = describes and explains the series of steps in an organic reaction
* Reaction mechanism for the substitution reaction with halogens is known as **free radical substitution**

### Free Radical Substitution

Consists of three major steps

1. Initiation (involves homolytic fission)
2. Propagation
3. Termination

Consider the overall reaction of CH4 and Cl2

+ -UV light-> +

Condensed Structural formula: CH4 + Cl2 -UV light-> CH3Cl + HCl

### Initiation Step

* Involves the formation of free radicals
* UV light provides the energy to break the Cl-Cl bond homolytically
* Cl2 -UV light-> 2Cl
* Produces free radicals of chlorine
* Free radicals
  + Contain an unpaired electron in one of their orbitals

### Heterolytic vs. Homolytic Fission

* A chemical bond between two atoms X and Y involves a shared pair of electrons
* The bond can be broken heterolytically or homolytically

### Heterolytic Fission

Bond breaks so that one atom has both electrons

X-Y -> X++Y- OR X-Y -> X- + Y+

### Homolytic Fission

Bonds breaks so that each atom has one electron

X-Y -> X + Y

## Propagation Steps

* Free radicals react to generate (propagate) new free radicals
* Once the UV light has initiated the formation of free radicals, that one radical can effectively go on to produce many molecules of products.

Cl + CH4 🡪 CH3 + HCl

CH3 + Cl2 🡪 CH3Cl + Cl

CH3Cl + Cl 🡪 CH2Cl + HCl

CH2Cl + Cl2 🡪 CH2Cl2 + Cl

## Termination Steps

* Free radicals can either
* Collide with the walls of the vessels
* Escape completely
* React with another free radical to produce a non-radical product

Cl + Cl -> Cl2

Cl + CH3 - > CH3Cl

CH3 + CH3 - > C2H6

# Organic chemistry lesson 3 part 1

## Alkenes

Hydrocarbons that contain one or more carbon-carbon double bond. The functional groups (double bonds) in this compound is termed “alkenyl”. They have the general formula CnH2n

## Alkynes

Hydrocarbons that contain one or more carbon-carbon triple bond. The functional group (triple bond) in this compound is termed “alkynyl”. They have the general formula CnH2n-2

*These compounds are unsaturated*

## Naming / Drawing:

1. Main chain must include the multiple bond (not necessarily the longest chain)
2. Replace “ane” with ene” for double bonds and “yne” for triple bonds
3. Start numbering carbons clocest to where the multiple bond starts
4. If 2 double bonds then “diene” if 3 then “triene”
5. Identify any substituents and number them

Examples: Name

CH2 = CH CH2 CH3

Name: but-1-ene

Hepta-2,5-diene

CH3CH=CH CH2 CH=CH CH3

Ethyne

Hex-3-yne

CH3 CH2 C ≡ C CH2 CH3

## Aromatic Hydrocarbons

Naphthalene = moth balls

### Naming / Drawing

* Consider benzene ring as the parent molecule for small alkane chains. (note: If alkane chain is long, benzene ring becomes a “phenyl” substituent)
* Name alkyl groups as branches
* If more than one alkyl group, they are numbered using the lowest numbers possible

Example:

1-methylbenzene / methylbenzene

3-phenylheptane

## Reactions of Alkenes and Alkynes

* Much more reactive than alkanes (addition of Br2 does not require a catalyst
* Undergo ADDITION reactions because there is no loss of hydrogen atoms

4 kinds of reactions:

1. Halogenation (with Br2 or Cl2)

+ Cl2 => 1,2-dichloroethane

1. Hydrogenation (with H2)

+ H2 + Ni Catalyst => ethane

For the next 2 examples, you will need to use “Markovinikov’s” rule: The richest get richer. When a hydrogen halide or water is added to an alkene or an alkyne, the hydrogen atom will bond to the carbon atom that already has more hydrogens.

1. Hydrohalogenation (with hydrogen halides)

+ HF + heat => 2-fluoropropane

There fore, major product is CH3 CHF CH3

Still, you will have some minor products as well

CH2F CH2 CH3

1. Hydration (with H2O)

+ H2O + H2SO4+ + heat =>

Therefore, major product is CH3 CHOH CH3

However, you will still have some minor products as well

CH2OH CH2 CH3

# Organic chemistry lesson 3 part 2

## Test for Unsaturation

* Bromine water can be used to distinguish between saturated and unsaturated hydrocarbons.
* Bromine water –yellow/orange coloured solution.
* If added to alkene, colour disappears.
* Reaction:

+ Br2 =>

+ Br2 => NR

## Structurial Isomers of alkenes:

Draw all the straight-chain structural isomers of C5H10

pent-1-ene

pent-2-ene

# Organic Chemistry lesson 4

### Electrophile

An electron-deficient species (e.g. a positive ion or positive end of a dipole) that can accept lone pair of electrons from a nucleophile.

### Nucleophile

An electron-rich species (e.g. a negative ion or negative end of a dipole) that can donate lon pair of electrons to an electrophile.

## Electrophilic Addition Reactions of Alkenes

+ HF + heat => 2-fluoropropane

Now we will look at how this reaction actually happens in more detail. This detailed reaction is called the Electrophilic Addition Mechanism.

1. Detailed electrophilic Addition Reaction Mechanism of:

+ δ+ H - F­ δ- + heat => + F2-=> 2-fluoropropane

Secondary carbocation – secondary because bonded to two carbons, carbocation because it is positive ion.

Minor product:

+ δ+ H - F­ δ- + heat =>+ F2- =>

Primary Carbocation – primary because bonded to one carbon

Therefore, the formation of the major product can be explained in terms of the relative stability of the possible carbocations in the reaction mechanism.

Secondary carbocations are more stable than primary carbocations.

This is directly related to Markovnikov’s Rule

1. Detailed Electrophilic Addition Reaction Mechanism of

+ δ+ Cl-Cl δ- => + =>

\*Electrons pushed away as the chlorines approach the electron dense double bonds.

## Electrophilic Substitution Reactions of Benzene

Recall the structure of benzene:

⬄

Remember that benzene has delocalized pi electrons. This represents regions of high electron density and therefore, benzene is susceptible to attacks by electrophiles.

Benzene can react with nitric acid to form nitrobenzene.

+ concentrated HNO3 heat under reflux 60 deg> H2O + (nitrobenzene)

This reaction can be shown in more detail. This detailed reaction is called the Electrophilic Substitution Mechanism.

HNO3 + 2H2SO4 🡪 NO2+ + H3O+ + 2HSO4-

+ NO2+  🡪 🡪 +H+

Benzene does NOT undergo addition reactions, Only substitution reactions!

Unlike alkyne, which always have additional reactions

# Organic Chemistry Lesson 5

## Alcohols

* The alcohol in wine and beer is ethanol and is formed as a waste product as yeast break down sugars
* Functional group is called “hydroxyl” and represented with “OH”. They have the general formula CnH2n+2O

## Naming

* Parent molecule is now the longest one with the “OH” group attached
* Take parent alkane name and drop “ane”. Suffix is now – “anol”
* Requires smallest possible number for functional group
* Name Alkyl side chains as before

Examples

propan-1-ol

e-ethylpentan-2-ol

## Polyalcohol

Contain more than one hydroxyl groups:

ethane-1,2-diol

ectane-2,4,7-triol

## 1o (Primary), 2o (Secondary), and 3o (Tertiary) alcohols

* Depends on the number of other carbon atoms that the carbon with the –OH group is attached to.

Example:

butan-1-ol

Primary alcohol

Carbon attached to OH is only attached to another carbon

CH3 CH­2 CH2 CH2 OH

butan-2-ol

Secondary alcohol

Carbon attached to OH is attached to two other carbons.

2-methylpropan-2-ol

Tertiary alcohol

Carbon attached to OH is attached to three other carbons.

Similarly, you can also have primary, secondary and tertiary halogenoalkanes.

## Cyclic Alcohols

In a ring format

Example: Cyclopropanol and phenol.

## Properties of alcohols:

* Are more polar than alkanes but less polar than water. (more soluable in water than alkanes).
* But, the longer the hydrocarbon chain that is attached to the alcohol, the more non-polar it becomes.
* Have the capacity to form hydrogen bonds so have higher mp/bp than regular hydrocarbons.

### Reactions of Alcohols:

1. Preparation of alcohols by hydration

But-1-ene

CH3 CH2 CH≡CH2 + H2O + H2SO4 + heat 🡪 CH3 CH2 CHOHCH3 (butan-2-ol)

1. Combustion of alcohols
   * Very similar to that of hydrocarbons

Propan-1-ol

2C3H8O + O2 🡪 8H2O + 6CO2

# Organic Chemistry Lesson 6

## Aldehydes

* Smaller aldehydes have unpleasant odours (formaldehyde). Larger ones have flowery odours. They are often found in the essential oil of plants.
* They have the general formula of CnH2nO. Functional group is called “carbonyl” and is represented as:
  + Always at the beginning of the chain, carbon number 1

### Naming

* Parent chain is now the longest one with the carbonyl group attached
* Parent alkane name and drop the “ane”. Suffix is now “anal”
* No need to number where the carbonyl group is found in aldehydes because its always at the beginning of the chain.

Examples

butanal

3-ethylhexanal

Draw:

### Properties of Aldehydes (and Ketones)

* Less soluble in water than alcohols because they do not have OH groups. (no H-bonds)
* But the C=O bond is polar so they are more soluble than hydrocarbons.

### Reactions of Aldehydes

Preparing aldehydes from alcohols (oxidation)

Primary alcohol + active oxygen [which comes from acidified potassium dichromate (VI) or Potassium Manganate (VII)] = Aldehyde

+ [O] + Cr2O7-2/H+ + Heat 🡪 H2O +

### Distillation

Used to separate liquids with different boiling points. (e.g. aldehyde has lower boiling point than alcohol). If you want to collect the aldehyde and separate it from the reactant alcohol you heat it up so the aldehyde evaporates and then you cool the aldehyde, thus allowing it to condense in a separate flask.

## Ketones

* They have odours
  + Nail polish remover is a ketone
  + Smell on the breath of a diabetic in insulin shock is a ketone
* They have the general formula of CnH2nO. Functional group is called “carbonyl” and is represented as

### Naming

* Parent chain is now longest one with the carbonyl group attached
* Take parent alkane name and drop “e”. Suffix is now “one”
* Smallest possible ketone is propan-2-one

Examples

Pentan-2-one

4-methylhexane-3-one

### Reactions of Ketones

Secondary alcohol + active oxygen = Ketone

+ [O] + Cr2O7-2/H+ + Heat 🡪 H2O +

--------------------------------------------------------------------------------------------------------------------------------------------------------

Tertiary alcohol + active oxygen = NO REACTION

+ [O] + Cr2O7-2/H+ + Heat 🡪 NO REACTION (Oxygen is not strong enough to take away the h from hydroxide and the methyl group.

# Organic Chemistry Lesson 7

Propan-2-one

## Carboxylic acids

* Carboxylic acids are found in many common household items: vinegar, citrus fruits
* The feeling that you get in your legs after running for a long time is caused by the build up of the carboxylic acid, “lactic acid”
* They have the general formula of CnH2n-1COOH. Functional group is called “carboxyl” and is represented as:

### Naming

Take the parent alkane name, drop the final “ane” and add suffix “anoic” followed by word “acid”

Example:

propanoic acid

Exception: with benzene you drop benzene

Example:

benzoic acid

Many acids have 2 carboxyl groups. In this case you use the suffix “dioic”

Example

ethanedioic acid

### Properties of Carboxylic acids

* The C=O and the OH groups makes the molecule polar. (more polar than aldehydes/ keytones, ethers, and hydrocarbons)
* Solubility in water is therefore comparable to that of alcohols
* They are acids and so have low pH values and undergo neutralization reactions with bases

### Reaction of Carboxylic acids

Preparing carboxylic acids

Oxidizing an aldehyde gives a carboxylic acid

+ [O] + Cr2O72- / H+ + head under reflux 🡪

+ [O] + Cr2O72- / H+ + head under reflux 🡪

In this reaction, heat Is needed, however, aldehydes have lower boiling points that carboxylic acids, therefore it this reaction were to proceed, the reactant would just boil off. This is where reflux comes in. Heating under reflux allows reactants with low boiling point to be heated for a long time without losing them. This is because a condenser is used to collect and condense the vapours of reactants that would normally escape, thus allowing them to complete the reaction.

## Esters

* Responsible for the smells of many fruits and flowers
* Functional group is called “ester” and is represented by:

### Naming of esters

* Ester name has 2 parts
  + The part containing the c=O is the parent chain. Drop “ane” from parent alkane and add “anoate”
  + The part of the chain lacking C=O is named like a substituent

Ethyl Butanoate

### Properties of Esters

* OR instead of OH, makes esters less polar than carboxylic acids and alcohols but more polar than ethers and hydrocarbons.
* Less soluble in water because less polar
* Not acidic

### Reactions of Esters

Preparation by condensation (esterification)

+ + H2SO4 + heat 🡪 H2O + ethyl butanoate