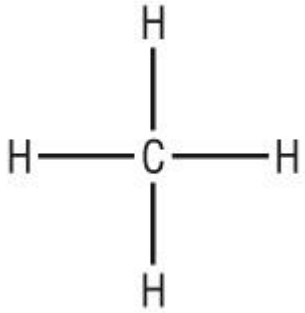
3.1 Introduction to Organic Chemistry

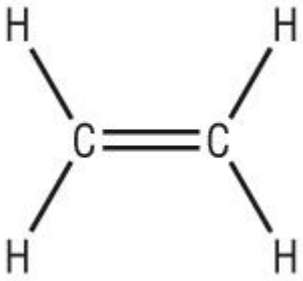
- **Organic Chemistry** is the study of carbon chemistry as carbon has the ability to join together in chains, rings, balls etc.
- Carbon also joins with other elements easily such as oxygen, hydrogen, nitrogen, phosphorous and the halogens.
- Carbon can join in many different ways and shapes.

Bonding in organic compounds:

- As carbon is in Gp4 of the periodic table it has 4 single outer shell electrons meaning it forms **4 covalent bonds only**.
- Carbon can form more than one bond with itself:

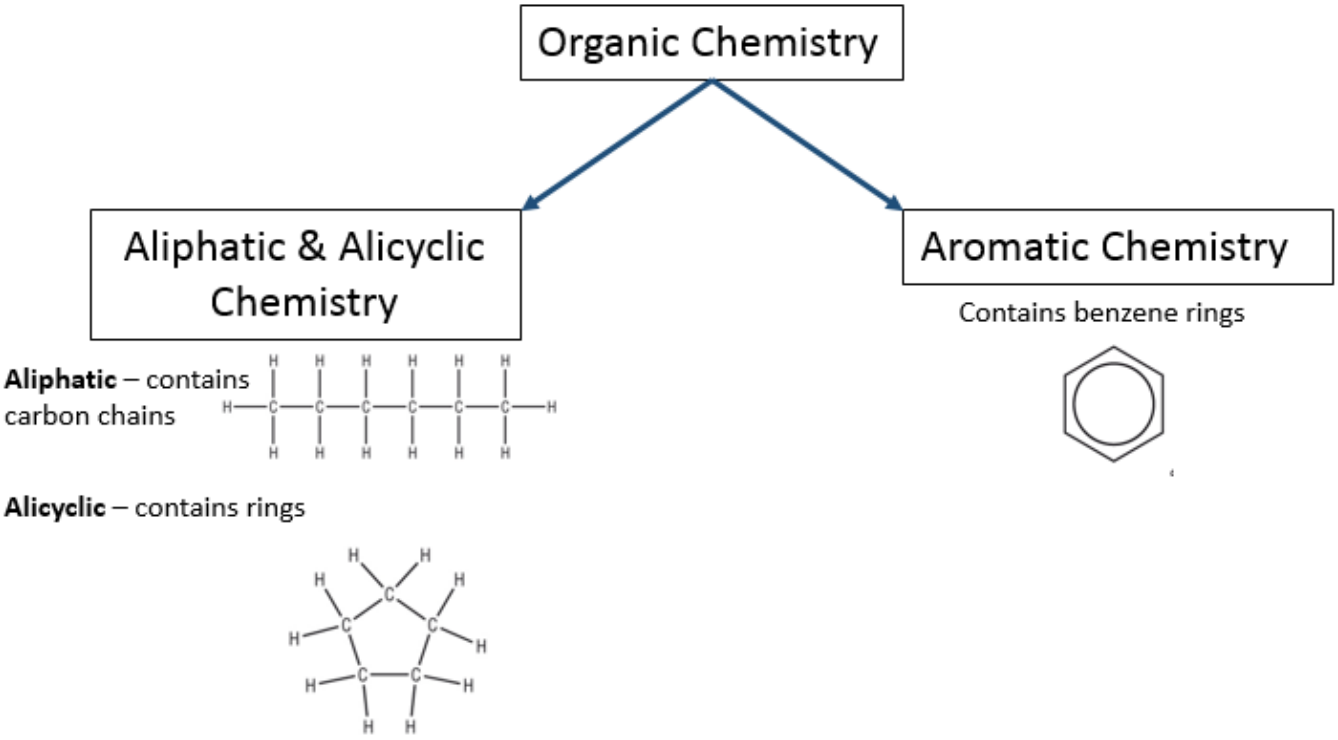


4 bonds only



A double bond and 2 single bonds to hydrogen = 4

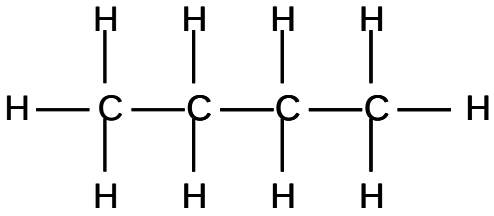
The Structure of Organic chemistry



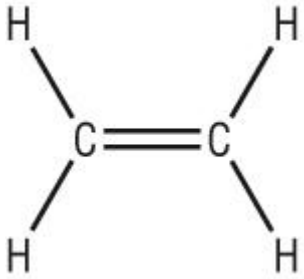
Definitions:

Hydrocarbon:
A compound that contains only hydrogen and carbon

Saturated:
A compound that contains single carbon – carbon bonds only



Unsaturated:
A compound that contains one or more carbon – carbon double bonds



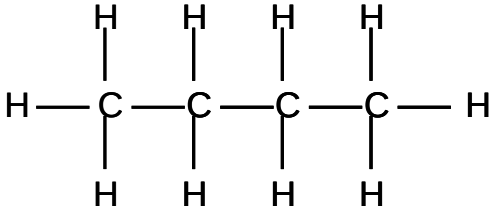
Molecular formula:
The actual number of atoms of each element in a compound

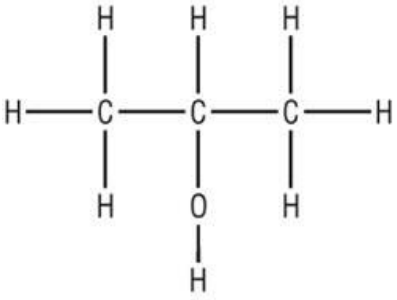
eg Hexane's molecular formula is C_6H_{14}

Empirical formula:
Simplest whole number ratio of atoms of each element in a compound

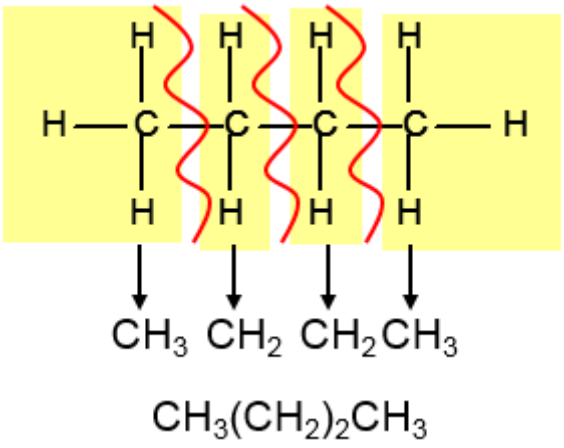
eg Hexane's empirical formula is C_3H_7

Displayed formula:
Shows all the atoms and bonds in a molecule



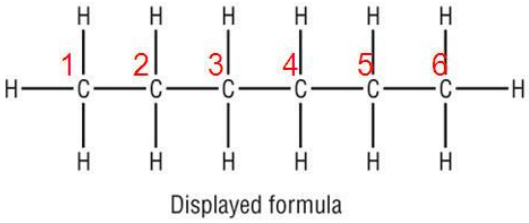


Structural formula:
Shows how the atoms in a molecule are arranged



Skeletal formula:
Shows the shape of the carbon skeleton

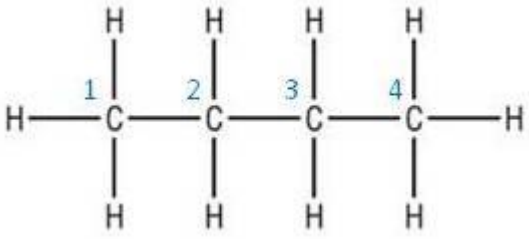
- A good way to approach this is to count and number the carbons. This can then be transposed to the carbon skeleton:



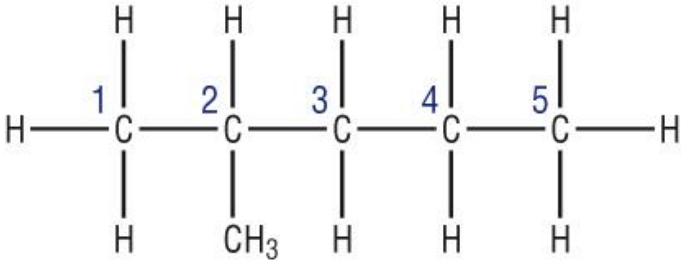
Displayed formula

Skeletal formula

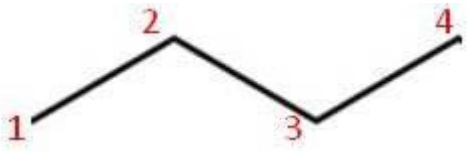
Further examples:

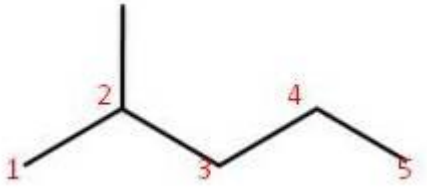


Structural formula:$CH_3CH_2CH_2CH_3$



Structural formula:$CH_3CH(CH_3)CH_2CH_2CH_3$





Homologous series:
Is a family of compounds containing the same functional group and having the same general formula. Each successive member has a different carbon chain length by CH_2

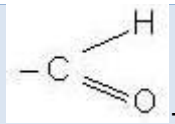
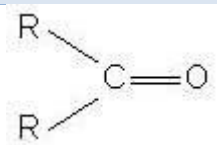
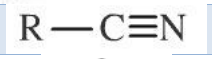
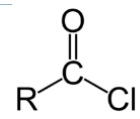
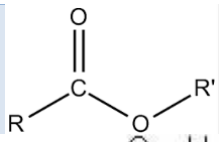
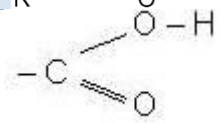
CH_3OH CH_3CH_2OH $CH_3CH_2CH_2OH$ $CH_3CH_2CH_2CH_2OH$

Functional group:
Is an atom or group of atoms which gives an organic compounds its particular chemical properties

Functional groups

- Organic Chemistry is studied in a systematic way because each different group of atoms attached to a carbon atom has its own characteristic set of reactions.

Increasing priority when naming ↓

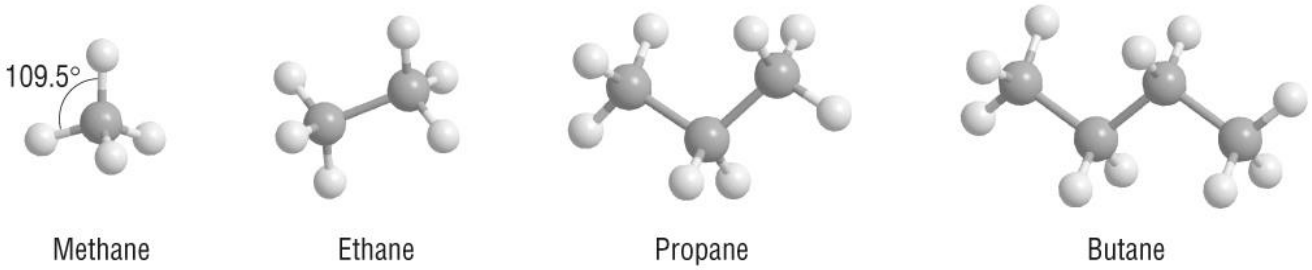
Functional group	Formula	Prefix (side chains)	Suffix (functional group)
Alkane	C - C		-ane
Halogenoalkane	– F	Floro -	
	– Cl	Chloro -	
	– Br	Bromo -	
	– I	Iodo -	
Alkene	C = C		-ene
Amine	– NH_2		-amine
Alcohols	– OH	Hydroxy - (if other functional groups are present)	- ol
Aldehydes	 - CHO		- al
Ketones			- one
Nitrile			– nitrile
Acyl chlorides			– oyl chloride
Ester			– oate
Carboxyllic acids			- oic acid

Nomenclature

- Naming organic compounds according to the **IUPAC system**

The Alkanes:

- This is a homologous series of saturated hydrocarbons:
- All the molecules end in **'ane'**



Methane Ethane Propane Butane

- The alkanes and their names are outlined in the table below:
- The number of carbons represent a name (later):

No of C's	Name	Formula
1	Methane	CH_4
2	Ethane	C_2H_6
3	Propane	C_3H_8
4	Butane	C_4H_{10}
5	Pentane	C_5H_{12}
6	Hexane	C_6H_{14}
7	Heptane	C_7H_{16}
8	Octane	C_8H_{18}
9	Nonane	C_9H_{20}
10	Decane	$C_{10}H_{22}$

- Organic molecules are usually made up from:
  Carbon chain
  Side chains (alkyl groups)
  Functional groups

- They are named in the following way

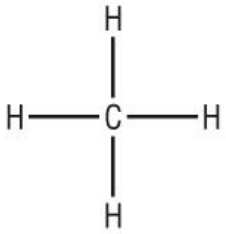
Stem
The longest carbon chain - the main name (in the middle)

Prefix
Added **before** the main name - pre - main name (side chains and some functional groups)

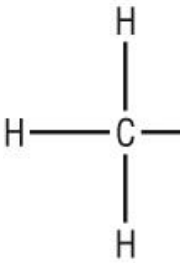
Suffix
Added **after** the main name - post - main name (functional groups)

Alkyl groups:

- If you remove a hydrogen from an alkane you have a group that has a bond that can join to the main carbon chain.
- Based on the alk**anes** the ending of these are changed to alk**yl**



Meth**ane**



Meth**yl**

- The first six alkyl side chains are in the table below:

No of C's	Name	Formula
1	Methyl	– CH_3
2	Ethyl	– C_2H_5
3	Propyl	– C_3H_7
4	Butyl	– C_4H_9
5	Pentyl	– C_5H_{11}
6	Hexyl	– C_6H_{13}

Naming rules:

1) Look for the longest continuous carbon chain – ***Stem***

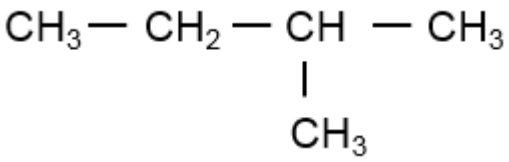
2a) Look for the functional groups – ***Suffix*** (can be a prefix)

2b) Count the position of the functional group and assign the lowest number. Use the lowest number – ***number goes between Stem and Suffix***

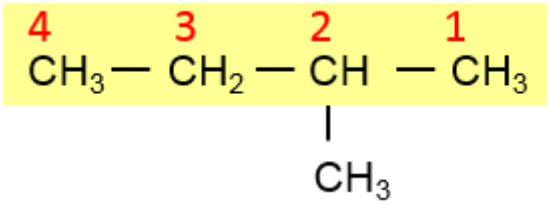
3a) Look for alkyl side chains – ***Prefix***

3b) Count the position of the alkyl side chain and assign the number in line with the count in (2) – ***number goes before the Prefix***

Example 1:-



1) Look for the longest continuous carbon chain – ***Stem***



4 carbons, therefore: ***… But…***

2a) Look for the functional groups – ***Suffix*** (can be a prefix)

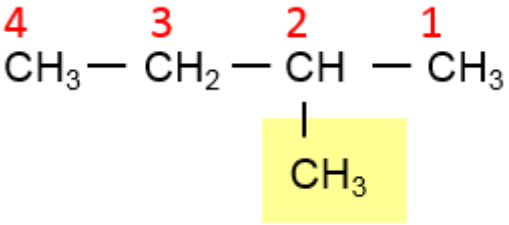
2b) Count the position of the functional group and assign the lowest number. Use the lowest number – ***number goes between Stem and Suffix***

No other functional groups except alkane, therefore: ***…ane***

…Butane

3a) Look for alkyl side chains – ***Prefix***

3b) Count the position of the alkyl side chain and assign the number in line with the count in (2) – ***number goes between Prefix and Stem***



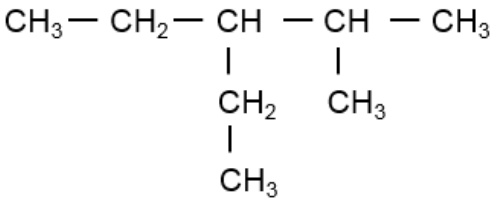
There's a methyl side chain on carbon '2', therefore: ***2 – methyl…***

2 – methylButane

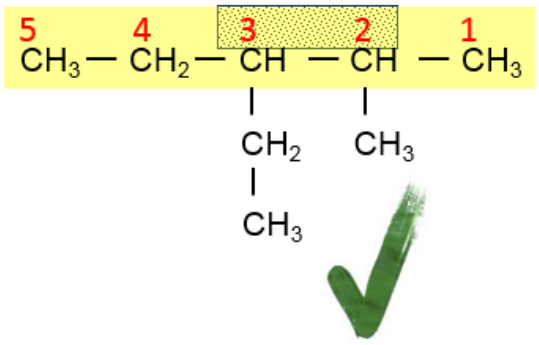
****However, as methyl can only ever be on C2, we drop the '2'***

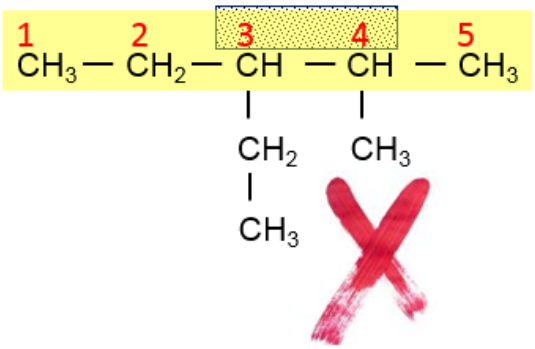
MethylButane

Example 2 - Additional side chains



1) Look for the longest continuous carbon chain – ***Stem***





5 carbons, therefore: ***… Pent…*** ***(keeping the numbers low)***

2a) Look for the functional groups – ***Suffix*** (can be a prefix)

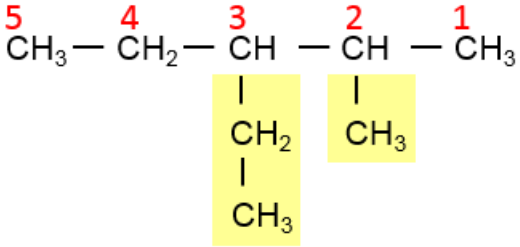
2b) Count the position of the functional group and assign the lowest number. Use the lowest number – ***number goes between Stem and Suffix***

No other functional groups except alkane, therefore: ***…ane***

…Pentane

3a) Look for alkyl side chains – ***Prefix***

3b) Count the position of the alkyl side chain and assign the number in line with the count in (2) – ***number goes between Prefix and Stem***

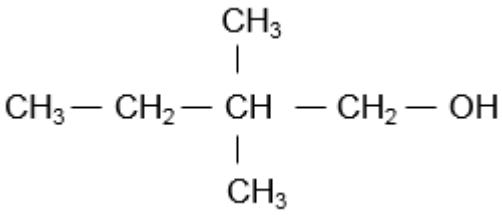


There's a 2 - methyl and a 3 – ethyl side chain, these are put in alphabetical order, therefore:

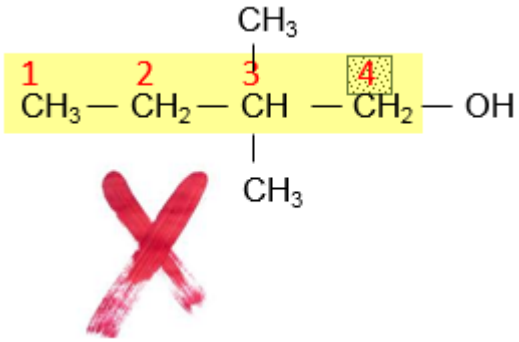
3 – ethyl, 2 – methyl…

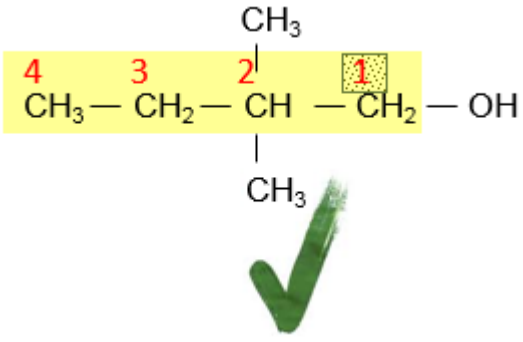
3 – ethyl, 2 – methylPentane

Example 3 - Side chains and a functional group



1) Look for the longest continuous carbon chain – ***Stem***





4 carbons, therefore: ***… But…*** ***(keeping the numbers low)***

2a) Look for the functional groups – ***Suffix*** (can be a prefix)

Alcohol functional group present …ol

- For functional groups that start with a vowel, insert ‘an’ on the end of the stem

…Butan…ol

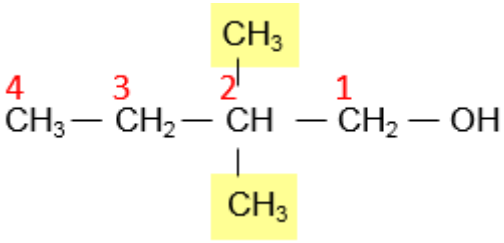
2b) Count the position of the functional group and assign the lowest number. Use the lowest number – ***number goes between Stem and Suffix***

Alcohol functional group on carbon 1, therefore …1 – ol

…Butan – 1 – ol

3a) Look for alkyl side chains – ***Prefix***

3b) Count the position of the alkyl side chain and assign the number in line with the count in (2) – ***number goes between Prefix and Stem***



There's are two 2 - methyl side groups

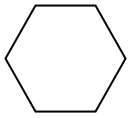
- For identical side groups of the same carbon we use di - 2, tri - 3, tetra - 4

2,2 - dimethyl…

2,2 – dimethylButan - 1 - ol

- Numbers are separated from names by hyphens.
- Numbers are separated from other numbers by commas

Example 4: Cyclic alkanes

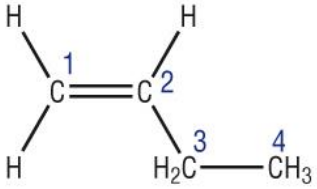


- If an alkane is cyclic we use the prefix '**Cyclo**'

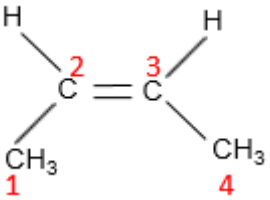
cyclohexane

Other examples:

- These contain a C=C, the ending of the name changes to ‘ene’ and we have to put a number to where the double bond is in the carbon chain:-

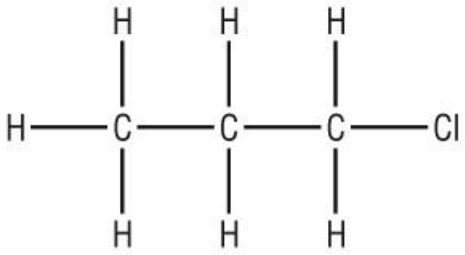


But – 1 – ene



But – 2 – ene

Names for Halogenoalkanes



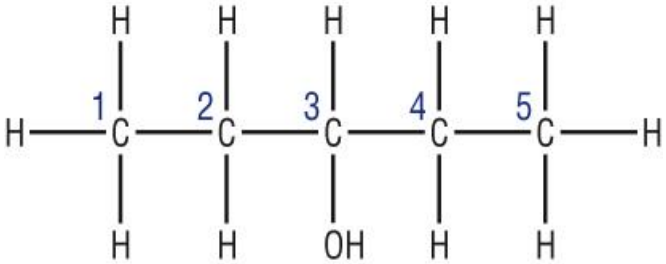
Stem - Longest chain = 3C = **prop**

Prefix - Functional group = **Chloro**prop

Chloro is on carbon 1 = **1** chloroprop

No suffix = ane = 1 chloroprop**ane**

Names for alcohols

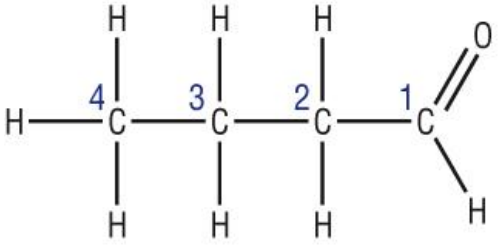


Stem - Longest chain = 5C = **pent**

Suffix - Functional group =OH (suffix starts with a vowel) = pent**an ol**

OH is on carbon 3 = pentan - **3** - ol

Names for aldehydes

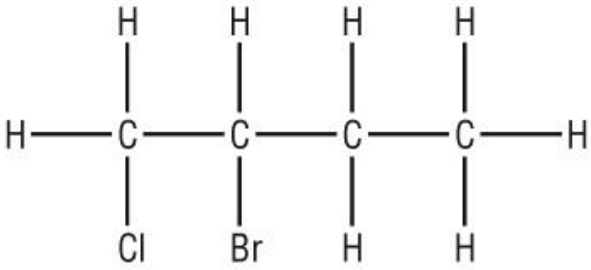


Stem - Longest chain = 4C = **but**

Suffix - Functional group = CHO (suffix starts with a vowel) = but**anal**

The 'al' does not need a number as all aldehydes are at the end of the molecule.

More than one of the same type of functional group



Stem - Longest chain = 4C = **but**

Prefix - Functional group = Cl on carbon 1

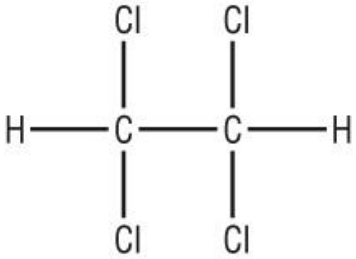
= **1 - chloro**

Functional group = Br on carbon 2 (prefix)n = **2 - bromo**

Functional groups are named alphabetically: **2 - bromo - 1 - chlorobut**

No suffix = ane = 2 - bromo - 1 - chlorobut**ane**

Names for many of the same functional groups:



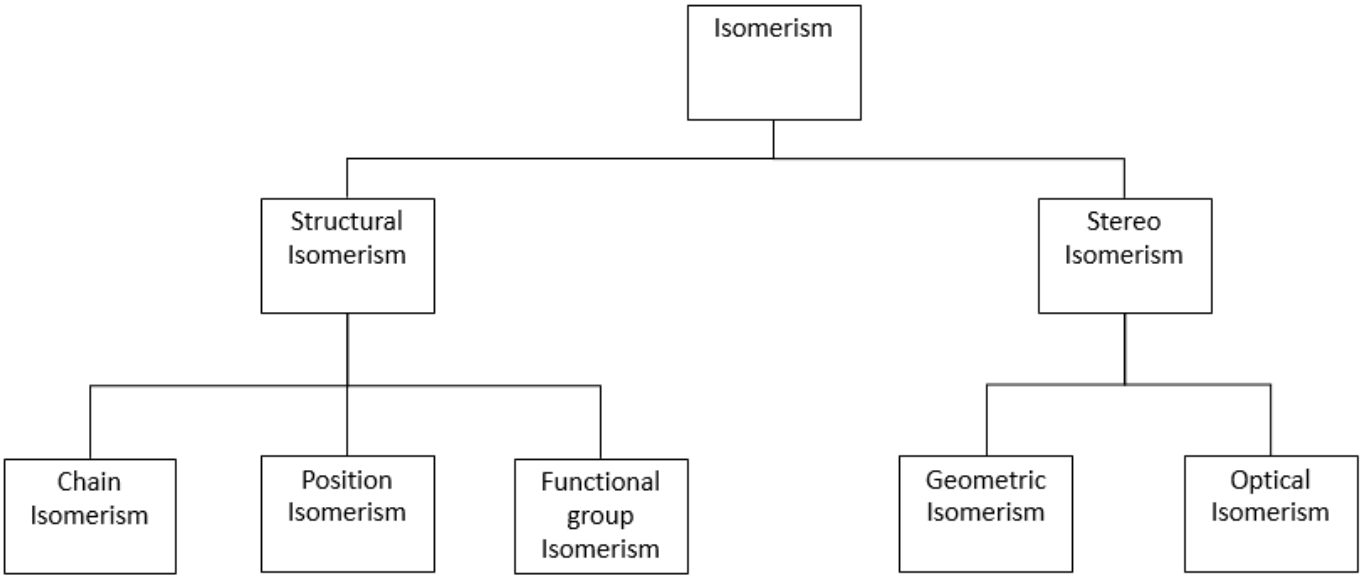
Longest chain = 2C = **eth**

Functional group = Cl, (2 x on carbon 1) and 2 x on carbon 2 (prefix), numbers first then how many chlorines: **1,1,2,2 - tetrachloro**eth

No suffix = ane = 1,1,2,2 - tetrachloroeth**ane**

Isomerism

- The molecular formula only tells you how many atoms of each element are present.
- It does not give you the structure.
- Molecules often have the same molecular formula but very different structures. These are called **Isomers** and there are many types.



Structural Isomers

- These have different structures using the same atoms.

> ***Structural Isomer:***
> ***Are compounds with the same molecular formula but a different structural formula***

- There are **3 types** of structural isomers

Stereo Isomers

- These have the same structures using the same atoms but the atoms are arranged differently in space.

> ***Stereo Isomer:***
> ***A Molecule with the same structural formula but its atoms are arranged differently in space***

- There are **2 types** of stereoisomers

1) Geometric or E/Z Isomerism (in Alkenes)
2) Optical (in A2 Year)

Activity 1:

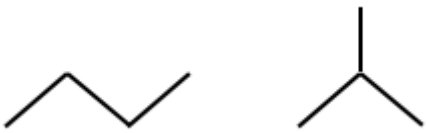
- Use the molymods to make and draw as many molecules as possible using all of 5 carbons and 12 hydrogens, C_5H_{12}.
- There are 3 different structures, draw these below:

Displayed formula			
Structural formula			
Skeletal formula			

- All of the molecules above contain the same number of atoms but they are arranged differently.
- They are different due to having different side groups or **chains**.
- This type of structural isomer is called **Chain Isomerism:**

1) <u>Chain Isomerism:</u>
These have the same molecular formula and functional group but a different arrangement of the carbon skeleton

Example:



Activity 2:

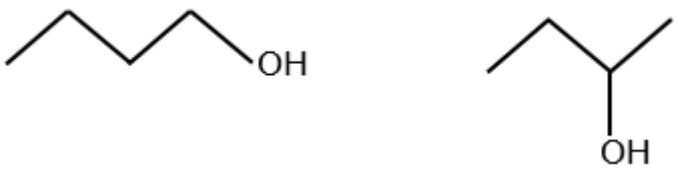
- Using the molymods make and draw as many molecules as possible using 3 carbons, 8 hydrogens, and 1 oxygen, C_3H_8O.
- Some of these structures that you have made will have different functional groups.
- There are 3 different structures, draw these below:

Displayed formula			
Structural formula			
Skeletal formula			

- All of the molecules above contain the same number of atoms but they are arranged differently.
- 2 of these are **alcohols** and these show **Position Isomerism**

> ***2) Position Isomerism:***
> ***These have the same molecular formula and functional group but the functional group is attached to a different carbon***

Example:



- The other molecule has a **different functional group** from the alcohols, (ether)
- These are called **Functional group Isomerism**

> ***3) Functional group Isomerism:***
> ***These have the same molecular but the atoms are arranged into a different functional group***

Example:

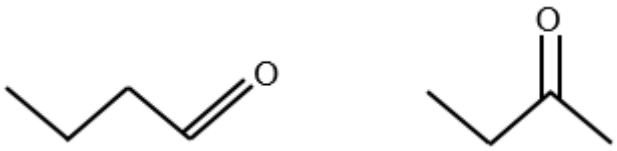
Activity 3:

- Using the molymods make and draw as many molecules as possible using 3 carbons, 6 hydrogens, and 1 oxygen, C_3H_6O.
- These structures will have different functional groups.
- There are 2 different structures, draw these below:

Displayed formula		
Structural formula		
Skeletal formula		

- The molecules above contain the same number of atoms but they are arranged differently.
- These molecules have a **different functional group** from each other.
- These are **Functional group Isomerism**

Example:



3) <u>Functional group Isomerism:</u>
These have the same molecular but the atoms are arranged into a different functional group

Organic reagents and their reactions:

Organic reactions

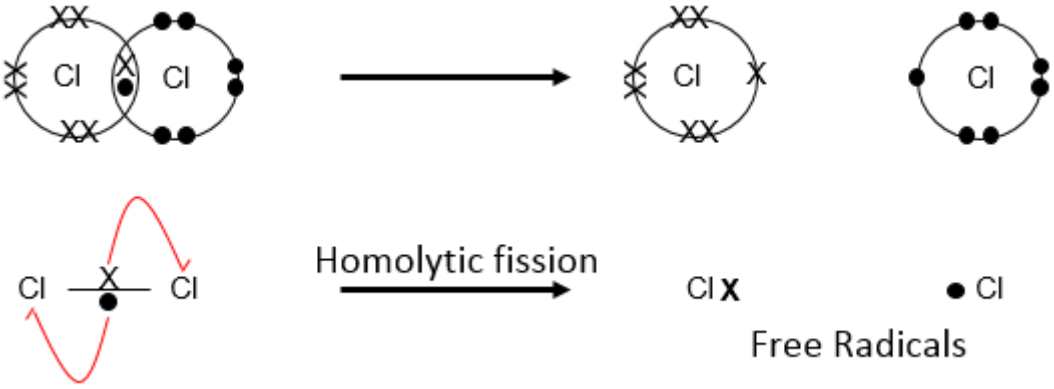
- **For a reaction to occur:**

A) A bond must break.
B) The breaking of a bond will form a reagent.
C) The reaction must take place

A) Bond breaking:

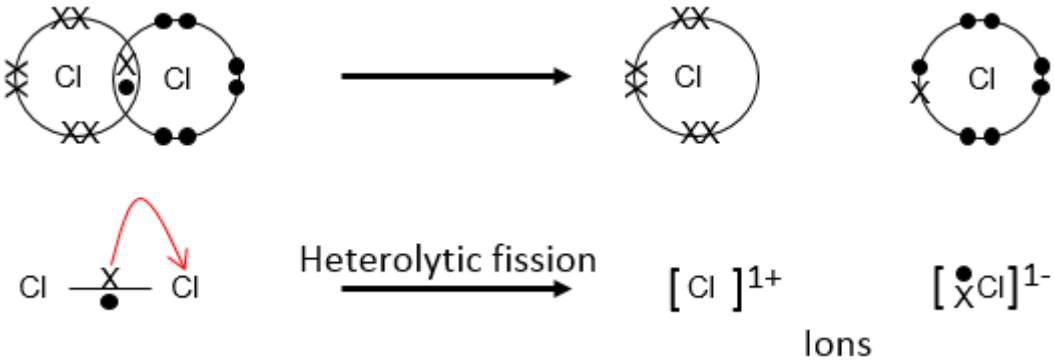
- For an organic reaction to occur, a covalent bond must be broken.
- Bond breaking is called **fission** and it can be broken in one of 2 ways:

1) Homolytic fission



- This is when the electrons in the bond go **'HOME'** to their parent atom.
- Each atom is the same. Homo….
- A half headed arrow represents the movement of 1 electron. This is because most reactions involve the movement of 2 electrons for which we use a normal headed arrow.
- **Free radicals** are atoms or groups of atoms with an unpaired electron, they are **extremely reactive** and are said to be **'short lived'**.

2) Heterolytic fission



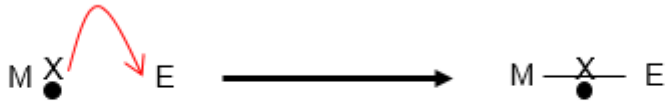
- This is when the electrons in the bond go to one of the atoms.
- A double headed arrow represents the movement of 2 electrons, a pair of electrons.
- The 2 resulting ions have a different number of electrons.
- It gives a positive ion and a negative ion.
- These are different from each other = hetero...

B) Types of reactants:

- Reactants start a reaction going.
- There are 3 types of reactants:

1) Free radical:
These are particles with an unpaired electron, Cl.

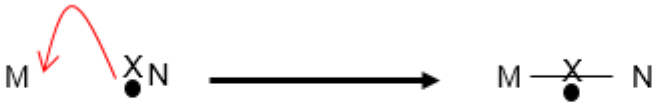
2) Electrophile:
These are electron pair acceptors



M: Molecule E: Electrophile – accepting a pair of electrons forming a bond

- These are often negative ions but must have a lone pair of electrons as these are donated to form a new covalent bond.
- Br^-, OH^-, H_2O, NH_3

3) Nucleophile:
These are electron pair donors



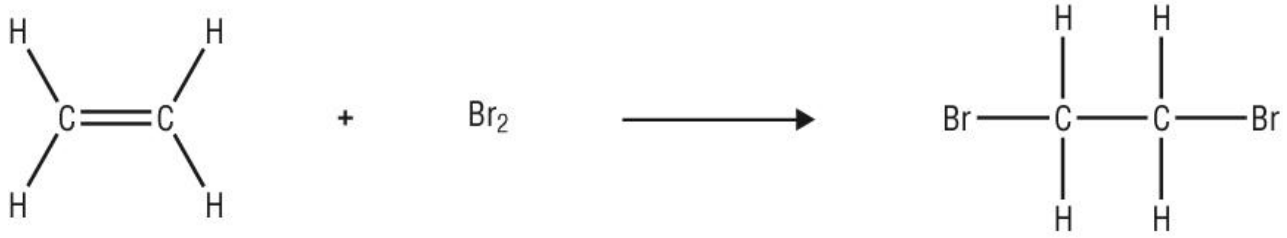
M: Molecule N: Nucleophile – donating a pair of electrons forming a bond

- These are often positive ions.
- Br_2, HBr, NO_2^+

C) Types of reaction:

1) Addition reactions

- Involves **2 molecules** joining to become **1 molecule**

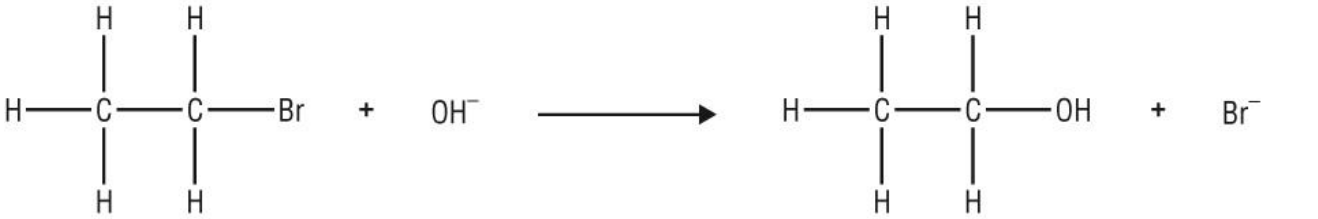


Ethene | Bromine (electrophile) | 1,2-dibromoethane

- Bromine has been **added** to ethene.

2) Substitution reactions

- Involves an atom (or group of atoms) being replaced by another atom (or group of atoms):
- **2 molecules** make **2 (new) molecules**

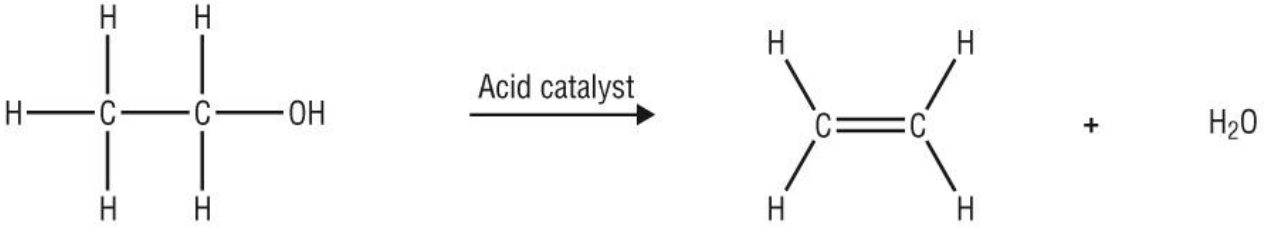


Bromoethane | Hydroxide ion (nucleophile) | Ethanol | Bromide ion

- You can see that the Br is being **substituted** by OH.

3) Elimination reactions

- Involves the removal of one molecule from another.
- **1 molecule** gives **2 molecules**:



Ethanol | Ethene | Water

- Water has been **eliminated** from ethanol