

CIE Chemistry A Level

14 : An introduction to Organic Chemistry Notes



Formulae, functional groups and naming of organic compounds

Naming organic compounds is something that you must be comfortable with in order to understand the rest of organic chemistry. You are required to be able to name organic compounds which have up to **6 carbons in a chain**.

Carbons in chain	1	2	3	4	5	6
Prefix	meth-	eth-	prop-	but-	pent-	hex-

There are different ways in which an organic compound can be displayed:



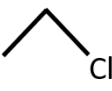
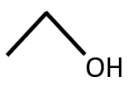
- **Molecular formula** - actual number of atoms of each element in a molecule.
- **Structural formula** - shows the structure carbon by carbon with hydrogens and functional groups attached.
- **Skeletal formula** - only shows the bonds on the carbon skeleton. The carbon and hydrogen atoms are not shown but any functional groups are. It can be used to simplify large complicated structures.
- **Displayed formula** - shows how all the atoms are arranged and every bond between them.

Examples of these different types of formula can be seen in the table below.

Table 1 and table 2 (**A level only**) show the different types of compounds you are expected to be able to name.

A **homologous series** is a group of compounds with the same **functional group**, with successive members differing by $-\text{CH}_2$.

Table 1: Aliphatic compounds

Homologous series	Prefix or suffix	Example name	Example molecular formula	Example structural formula	Example skeletal formula	Example displayed formula
Alkanes	-ane	Propane	C_3H_8	$\text{CH}_3\text{CH}_2\text{CH}_3$		$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$
Alkenes	-ene	Ethene	C_2H_4	CH_2CH_2		$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} & \\ & / & \diagdown \\ \text{H} & & \text{H} \end{array}$
Halogenoalkanes	Fluoro- Chloro- Bromo- Iodo-	Chloroethane	$\text{C}_2\text{H}_5\text{Cl}$	$\text{CH}_3\text{CH}_2\text{Cl}$		$\begin{array}{c} \text{H} & \text{Cl} \\ & \\ \text{H}-\text{C}-\text{C}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$
Alcohols	-ol	Ethanol	$\text{C}_2\text{H}_5\text{O}$	$\text{CH}_3\text{CH}_2\text{OH}$		$\begin{array}{c} \text{H} & \text{O}-\text{H} \\ & \\ \text{H}-\text{C}-\text{C}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$



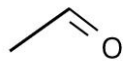
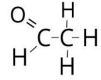

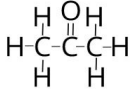
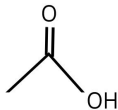
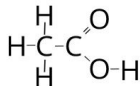
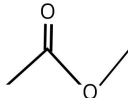
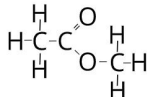
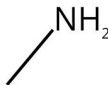
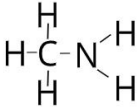

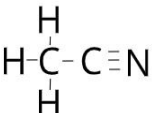
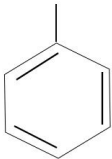
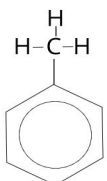
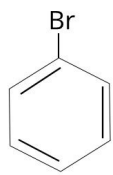
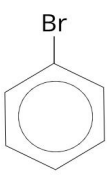
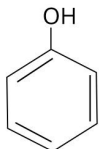
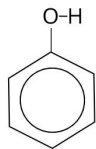
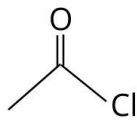
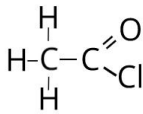
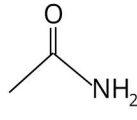
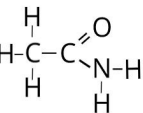
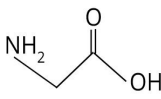
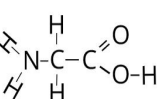
Aldehydes	-al	Ethanal	C_2H_4O	CH_3CHO		
Ketones	-one	Propanone	C_3H_6O	CH_3COCH_3		
Carboxylic acids	-oic acid	Ethanoic acid	$C_2H_4O_2$	CH_3COOH		
Esters	Alkyl- -oate	Methyl ethanoate	$C_3H_6O_2$	CH_3COOCH_3		
Amines	-amine	methylamine	CH_5N	CH_3NH_2		
Nitriles	-nitrile	Ethane nitrile	C_2H_3N	CH_3CN		

Table 2: (A Level only)

Homologous series	Prefix or suffix	Example name	Example molecular formula	Example structural formula	Example skeletal formula	Example displayed formula
Arenes	-benzene Or phenyl-	methylbenzene	C_7H_8	$C_6H_5CH_3$		
Halogenoarenes	Fluoro- /Chloro- /Bromo- /Iodo- -benzene	bromobenzene	C_6H_5Br	C_6H_5Br		
Phenols	-phenol Or -benzenol	Phenol	C_6H_6O	C_6H_5OH		



Acyl chlorides	-oyl chloride	Ethanoyl chloride	C_2H_3OCl	CH_3COCl		
Amides	-amide	Ethanamide	C_2H_5NO	CH_3CONH_2		
Amino acids	Amino- -oic acid	Aminoethanoic acid	$C_2H_5O_2N$	H_2NCH_2COOH		

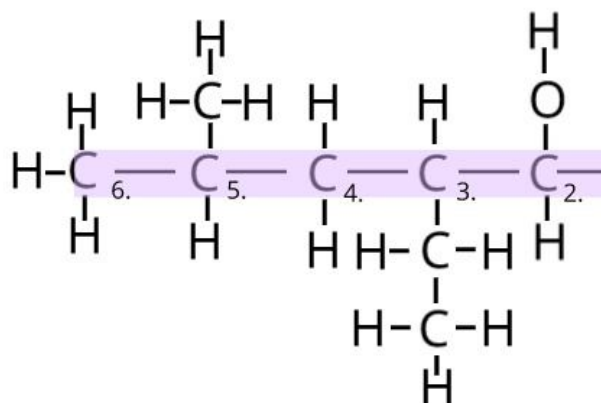
Naming organic compounds

Follow these rules when naming organic compounds:

1. Identify the **longest carbon chain** that contains the functional group.
2. Identify the **functional group** on the chain. This gives you the suffix or prefix of the compound.
3. Count along the carbon chain so that the **functional group has the lowest number**. See the example below to illustrate this.
4. If there are any **side chains**, add these as **prefixes** (e.g. methyl-) to the beginning of the name. Do the same if there are other (less important) functional groups. Put these at the start of the name in **alphabetical order**.
5. If there are **two or more identical functional groups** or side chains use the prefixes di-, tri- and tetra- before that section of the name.

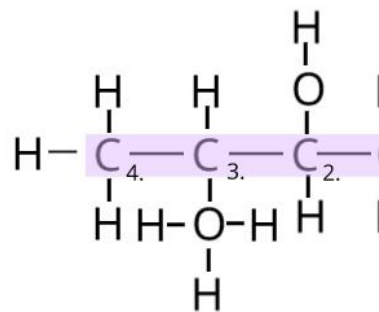
Example:

1. The longest carbon chain is **6 carbons long** so the prefix is hex-.
2. The most important functional group on the chain is the **-OH** alcohol. The suffix is therefore -ol.
3. The alcohol is on **the second carbon** in the chain (count from the side closest to this functional group). The suffix becomes **-2-ol**.
4. There are **two side chains**:
 An ethyl on the third carbon: 3-ethyl
 A methyl on the fifth carbon: 5-methyl
5. Place the prefixes in alphabetical order and add them to the name:
3-ethyl-5-methylhexanol.



Example 2:

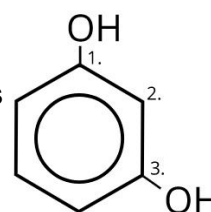
1. This chain is **symmetrical** so it does not matter which way the carbons are numbered. Prefix: but-
2. There are **two alcohol groups** on the second and third carbon: -2,3-diol.
3. There are no other groups so the overall name is: **butan-2,3-diol**.


Naming simple aromatic compounds (A Level only)

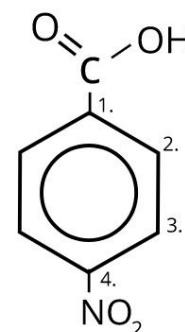
When it comes to naming aromatic compounds, the method to go about it is similar to the one above. The main difference is the **benzene ring** which means you count the carbons in the circle.

Example:

1. There are **two alcohol groups** on the benzene. This means the suffix is **-benzenol**, as seen in the table above.
2. Counting from the first alcohol as '1', the second alcohol group is on the third carbon in the chain. This gives the overall name **benzene-1,3-diol**.


Example 2:

1. The biggest group on the benzene chain is the **carboxylic acid** so start counting from there. The **nitro-group** is on the fourth carbon.
2. The overall name therefore is: **4-nitrobenzoic acid**.


Characteristic organic reactions terminology

The following terms are important in organic chemistry so you must make sure you are familiar with them:

- **Functional group** - a group of atoms responsible for the characteristic reactions of an organic compound.
- **Homolytic fission** - the splitting of a covalent bond where each atom retains one electron from the bonding pair.
- **Heterolytic fission** - the splitting of a covalent bond where one atom retains both electrons from the bonding pair.
- **Free radical** - an uncharged molecule with an unpaired electron.
- **Initiation** - an initial chemical reaction which triggers further reactions.
- **Propagation** - a secondary reaction where there is no net gain or loss of free radicals.



- **Termination** - the final step in a chain reaction where a reactive intermediate is rendered inactive.
- **Nucleophile** - a molecule or substance that donates electrons.
- **Electrophile** - a molecule or substance that acts as an electron pair acceptor.
- **Addition** - a reaction where two or more molecules react to form a larger molecule.
- **Substitution** - a reaction where an atom or group is replaced by another atom or group.
- **Elimination** - a reaction in which two substituents are removed from a molecule in a mechanism with one or two steps.
- **Hydrolysis** - the splitting up of a compound or molecule using water.
- **Condensation** - the formation of a compound with the release of water.
- **Oxidation** - loss of electrons.
- **Reduction** - gain of electrons.

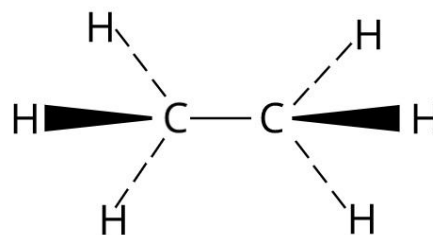
Shapes of organic molecules

Bonding in ethane

The shape of an ethane molecule (seen on the right) is **tetrahedral** with bond angles of **109.5°**.

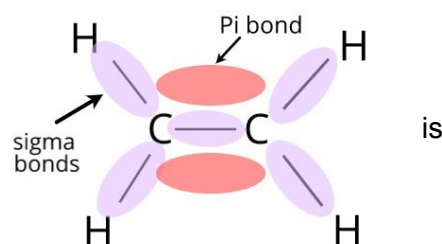
The bonds between each atom are **sigma (σ) bonds**.

Rotation can occur around sigma bonds because they are formed when two orbitals overlap end-to-end.



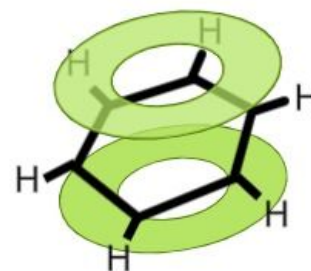
Bonding in ethene

Ethene molecules have a **trigonal planar** shape with bond angles of **120°**. These molecules contain both sigma and pi bonds (see diagram). The molecule is planar because there is **restricted rotation** around the C=C pi (π) bond. Rotation is restricted around this bond because a pi bond is formed when orbitals overlap below and above the plane of atoms.



Bonding in benzene (A Level only)

Benzene is a **planar molecule** with bond angles of **120°**. All the carbon-to-carbon bonds are identical so it has a regular hexagonal shape. There are C-H and C-C sigma bonds as well as a **delocalised pi system** above and below the carbon ring. One electron from each carbon is delocalised into the pi (π) system which **contains 6 electrons**.



Isomerism

Structural isomers

Isomers are molecules with the **same molecular formula** but a different arrangement of **atoms in space**. There are different types of structural isomerism:

- **Chain** isomerism: This occurs when there is branching on the carbon chain.
- **Functional group** isomerism: The functional groups on the carbon chain changes.
- **Positional** isomerism: The basic carbon chain, the backbone, remains the same but the groups attached to the chain move around and change position.

Structural isomerism	Isomer 1	Isomer 2
Chain	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	$\text{C}(\text{CH}_3)_4$
Functional group	CH_3COCH_3 (ketone)	$\text{CH}_3\text{CH}_2\text{CHO}$ (aldehyde)
Position	$\text{CH}_3\text{CH}=\text{CHCH}_3$	$\text{CH}_2=\text{CHCH}_2\text{CH}_3$

Stereoisomerism

Stereoisomers are molecules with the **same molecular and structural formula** but a different arrangement of **atoms in space**.

Geometrical (cis-trans)

Geometrical isomerism is a branch of stereoisomerism. It can also be called **cis-trans or E/Z isomerism**. This occurs due to a pi bond which **restricted rotation** around the C=C double bond. Since there is restricted rotation around this bond, the **various groups attached** to the carbon are **fixed in position** meaning different isomers can form. Examples of this type of isomerism are shown below (see example 1 in 'Isomerism in alkenes').

Optical isomerism

Optical isomerism is another branch of stereoisomerism. It occurs when there is a **chiral centre**, (explained in more depth in 'What is a chiral centre?' on the following page). Optical isomers have the same molecular and structural formula but they are **mirror images of one another**.

Isomerism in alkenes

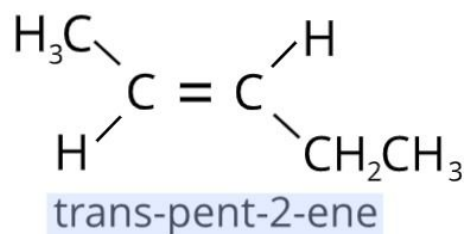
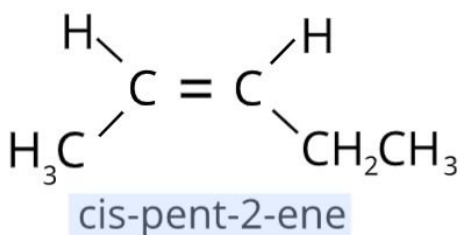
Geometrical isomerism is the type of isomerism that occurs in alkenes because it relies on a C=C double bond. The **cis isomer** has **both of the highest priority groups on the same end** (either both above or below the C=C bond). The **trans isomer** the highest priority groups **diagonally across** from each other, on opposite sides of the double bond.

The priority of a group is decided by **atomic number**. If the attached groups are different but the first atom joined from each group is the same then you work along each group simultaneously until you reach an atom with a different atomic mass to decide which has priority. A **higher atomic mass means a higher priority**.



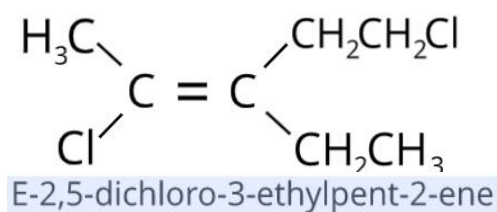
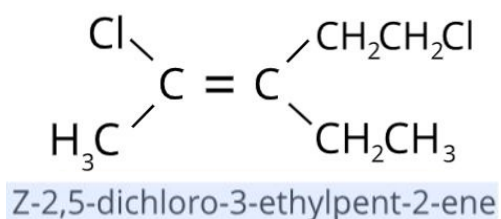
Example 1:

For the isomers below, the highest priority group on the left hand side is the methyl group, CH_3 , and on the right hand side it is the ethyl group, CH_2CH_3 .



Example 2:

For the isomers below, the priority group for the left hand side is the chlorine atom since it has a higher atomic mass than carbon in the methyl group. On the right hand side the groups are similar so you work along the chain until the chlorine atom which gives priority to the group with chlorine.



What is a chiral centre?

A chiral centre is an **atom with four different groups bonded** to it. This arrangement creates compounds which are **non-superimposable mirror images** of each other. If a compound has a chiral centre, it will display **optical isomerism**.

It is possible for compounds to have **more than one chiral centre**.

Spotting chiral centres:

Chiral centres can be spotted in organic compounds by identifying a **carbon atom which is bonded to four different groups**.

Example:

The carbon highlighted in the compound below is a **chiral centre** since it has bonded to four different groups: a hydrogen atom, a methyl group, an alcohol group and an ethyl group.



This compound displays **optical isomerism**. The isomers can be drawn in a **tetrahedral** shape with the chiral carbon at the centre. It is easiest to draw these isomers by drawing one then **mirroring** it on the other side of the page:



