



## Organic Chemistry 1 - Key concepts and Optical Isomerism

To succeed in this topic you need to:

- Understand organic nomenclature (covered in Factsheet 15 - Organic chemistry I - Nomenclature);
- Be able to name and draw organic molecules;
- Learn the reaction equations, conditions and mechanism names for the organic reactions met at AS-level (Factsheets 16 and 17).

After working through this Factsheet you will:

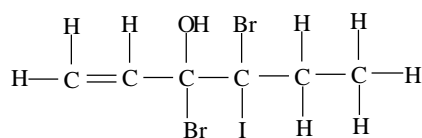
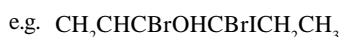
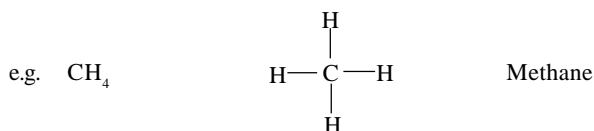
- Have recapped the chemical terminology learnt in AS-level;
- Have revised the organic reactions introduced at AS-level;
- Have revised structural and geometric isomerism;
- Understand how optical isomerism arises and be able to state whether or not it is present in a given molecule.

### Key definitions:

- **Functional Group** - the reactive part of a molecule.
- **Family of compounds** - contain the same functional group.
- **Homologous Series** - a series in which the compounds belong to the same family and only differ by a  $-CH_2-$  group in the length of the carbon chain.
- **General Formula** - represents a homologous series of a family of compounds.  
e.g.  $C_nH_{2n+2}$  - alkanes.  
 $C_nH_{2n+1}OH$  - alcohols.

### IUPAC Nomenclature

The agreed international system of naming organic compounds, or 'systematic nomenclature', is explained in detail in Factsheet 15. Candidates **must** have a good understanding of this, and be able to name simple and complex organic molecules.



3,4-dibromo-4-iodohex-1-ene-3-ol

Refer to Factsheet 15 for the method of naming organic compounds, worked examples, and questions.

### Functional Groups

These functional groups are the ones introduced in the AS-level course.

Family	Functional Group	Systematic Name
Alkane	C – C	-ane
Alkene	C=C	-ene
Alcohol	-OH	-ol
Halogenoalkane	-Cl	chloro-
	-Br	bromo-
	-I	iodo-
Ketone	$\begin{array}{c} \diagup \\ \text{C}=\text{O} \\ \diagdown \end{array}$	-one
Aldehyde	$\begin{array}{c} \text{H} \\   \\ -\text{C}=\text{O} \end{array}$	-al
Carboxylic Acid	$\begin{array}{c} \text{OH} \\ / \\ -\text{C} \\ \backslash \\ \text{O} \end{array}$	-oic acid
Nitrile	-CN	-nitrile
Amine	-NH <sub>2</sub>	-amine

**Exam Hint:** Candidates should ensure they are adept at switching between the systematic name of a compound and its structure. This skill will usually be assumed in A2 work.

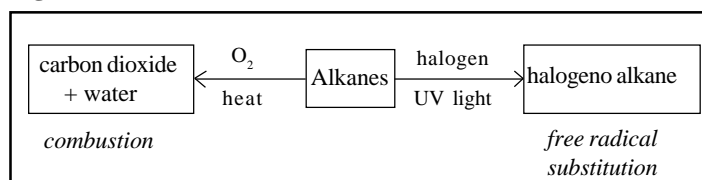
The following terms are used in describing and classifying reactions

### Glossary of terms

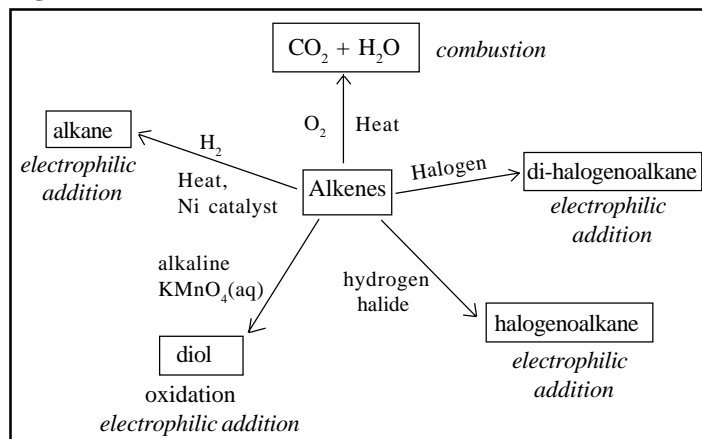
Free radical	A species with an unpaired electron.	Substitution	When an atom or 'group' in a molecule is replaced by another atom or 'group'.
Nucleophile	A donator of a lone pair of electrons (to form a new covalent bond). N.B. Nucleophile means 'nucleus (+ve charge) lover'.	Addition	When 2 molecules react to form a single product.
Electrophile	An acceptor of a lone pair of electrons (to form a new covalent bond). N.B. Electrophile means 'electron lover'.	Elimination	When a simple molecule (e.g. HCl, HBr, H <sub>2</sub> O) is removed from a molecule and not replaced.
Homolytic fission	When a covalent bond breaks and one electron goes to <i>each</i> atom (forming free radicals).	Hydrolysis	When water reacts with a molecule, and the molecule is split into two parts.
Heterolytic fission	When a covalent bond breaks and both electrons go to one atom (forming ions).	Oxidation	Loss of electrons, gain of oxygen or loss of hydrogen.
		Reduction	Gain of electrons, loss of oxygen or gain of hydrogen.
		Polymerisation	Formation of polymer molecules from monomers.

The diagrams below summarise the organic reactions from AS Chemistry - Factsheets 16 and 17 cover the full details and equations.

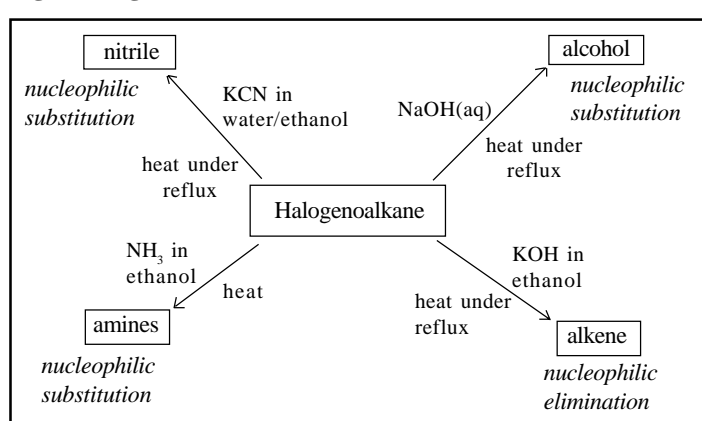
**Fig. 1 Alkane reactions**



**Fig. 2 Alkene reactions**



**Fig. 3 Halogenoalkane reactions**

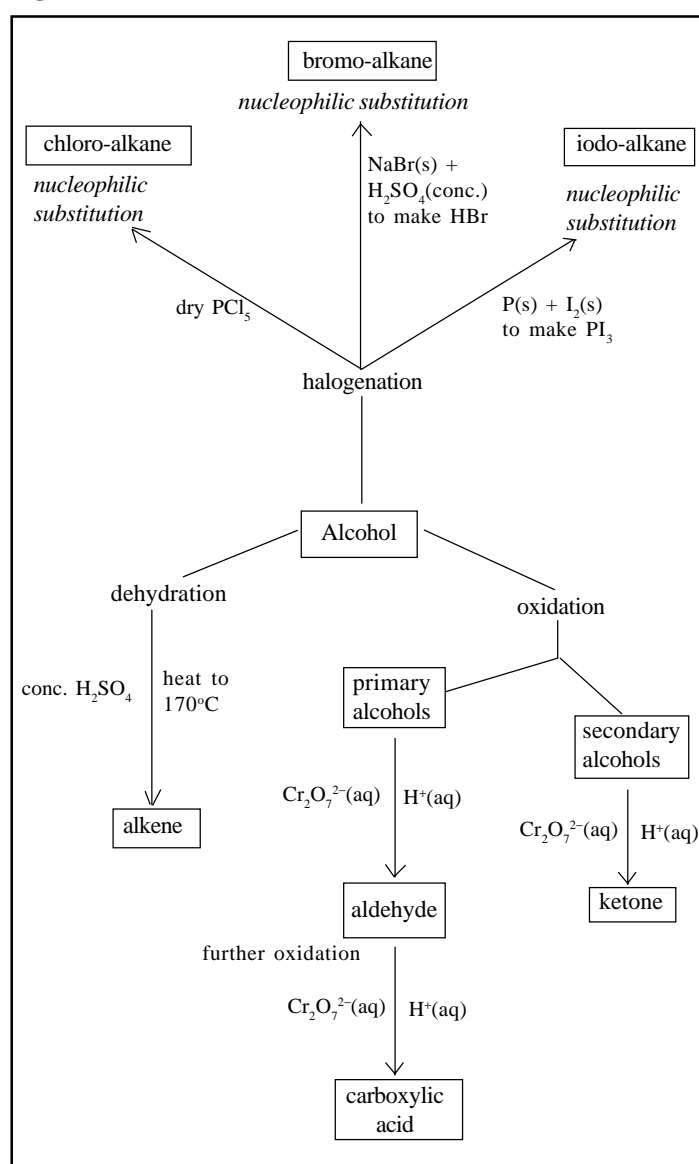


### Exam Hint:

Candidates must *learn* the following about each organic reaction.

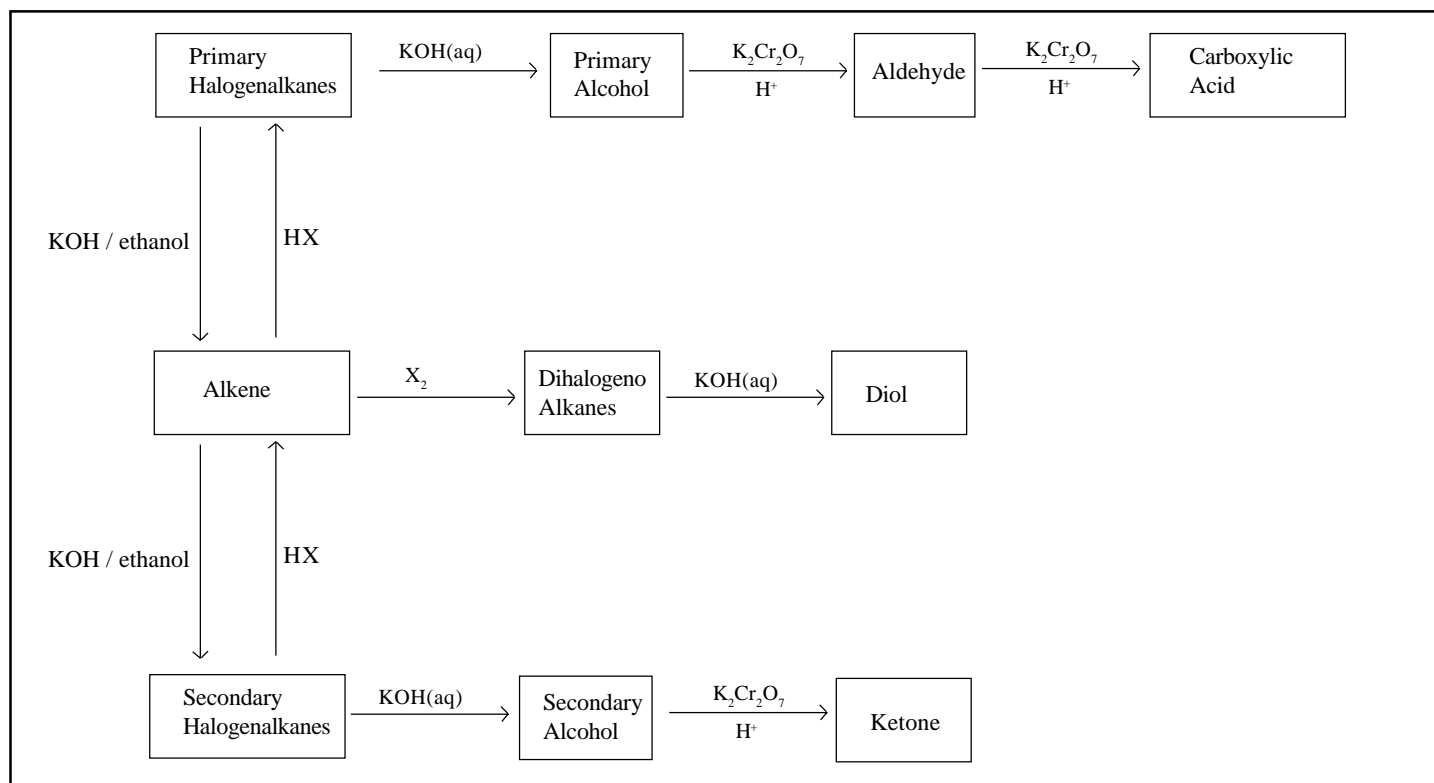
- Reaction equation.
- Reaction conditions.
- Reaction type and mechanism.

**Fig. 4 Alcohol reactions**



Once these reactions have been learnt, candidates should then begin to see how organic compounds can be inter-converted, as 'synthetic pathways' can be understood.

Fig 5. Synthetic pathways summary



### Tests for functional groups

Candidates are expected to know the following tests for functional groups in practical exams / assessments and modular exams.

Group / Family	Test	Result
Alkene C=C	Shake with bromine water, Br <sub>2</sub> (aq)	Colour of bromine solution goes from brown to colourless.
Chloroalkane C-Cl	1. Warm with NaOH(aq)	White precipitate, soluble in dilute NH <sub>3</sub> (aq).
Bromoalkane C-Br	2. Add dilute HNO <sub>3</sub> (aq), until just acidic	Cream precipitate, soluble in conc. NH <sub>3</sub> (aq).
Iodoalkane	3. Add AgNO <sub>3</sub> (aq)	Yellow precipitate, insoluble in conc. NH <sub>3</sub> (aq).

### Isomerism

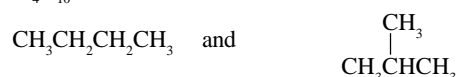
Isomerism is the term used for compounds with the same molecular formula (i.e. the same number of atoms of each type) that have different arrangements of these atoms.

At A2-level there are 3 types of isomerism to learn about:

#### 1. Structural Isomerism

Structural isomerism is when the same number and type of atoms can be arranged in different ways to form structural isomers.

e.g. C<sub>4</sub>H<sub>10</sub> has 2 structural isomers.

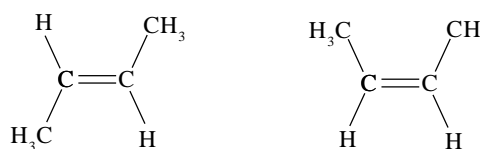


**Exam Hint:** A common exam question is for candidates to be given a formula and to be asked to work out a number of different structural isomers, so practise this!

#### 2. Geometric Isomerism

Geometric isomerism is caused by the presence of a carbon-carbon double bond (C=C). There is no rotation about the C=C because rotating would require breaking the pi-bond. The two forms are called **stereoisomers**.

e.g. But-2-ene, C<sub>4</sub>H<sub>8</sub>, is the smallest molecule showing geometric isomerism.



**Trans-but-2-ene**  
The H atoms are diagonally across ("trans") the double bond.

**Cis-but-2-ene**  
The H atoms are the same side ("cis") of the double bond.

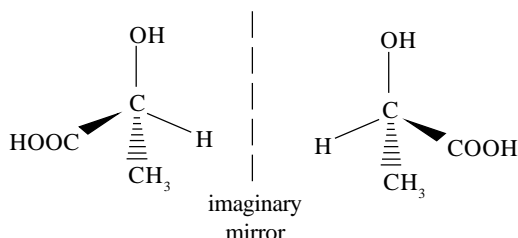
Geometric isomers can only occur if both carbon atoms involved in the double bond have two different groups attached to them.

## 3. Optical Isomerism

Optical isomers are defined as isomers of which one is the non-superimposable mirror image of the other. Such molecules are said to be **chiral molecules**.

This can be caused by a carbon atom having 4 different groups attached to it. This carbon atom is called the **chiral centre**.

e.g. The optical isomers of lactic acid.



They are known as 'optical' isomers, as a single optical isomer has the ability to rotate the plane of polarisation of plane-polarised monochromatic light.

Isomers which rotate the plane to the **right (clockwise)** are **dextrorotatory** and given the prefix (+).

Isomers which rotate the plane to the **left (anticlockwise)** are **laevorotatory** and given the prefix (-).

If a solution contains equal amounts of 2 optical isomers (e.g. 1 mole of (+)-alanine and 1 mole of (-)-alanine) it is said to be a **racemic mixture**, and will show **no rotation**, as the effects of each optical isomer cancel out.

Geometric and optical isomerism are both forms of **stereoisomerism**.

## Practice Questions

- (a) Give the formula of the three **structural** isomers of  $C_4H_8$  which are non-cyclic.
  - One of these structures shows a type of stereoisomerism.
    - Explain what causes the existence of stereoisomerism.
    - Give the two structures of the stereoisomers and name them.
- Draw the structures of the following organic compounds.
  - Propene
  - Pentan-2-ol
  - Triiodomethane
  - 2,2-dichloro-4-bromohex-3-ene-5-ol
- Define the following terms.
  - Free radical.
  - Electrophile.
  - Substitution.
  - Hydrolysis.
- The question relates to the following reaction scheme.

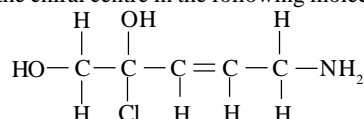


- Give the conditions and equations for
    - Step 1.
    - Step 2.
  - What is the type and mechanism of the reaction in step 2?
- The question relates to the following reaction scheme.



- Give the conditions required and the equation for:
  - Step 1.
  - Step 2.
- What is the type and mechanism of the reaction in step 2?

- (a) Mark the chiral centre in the following molecule.

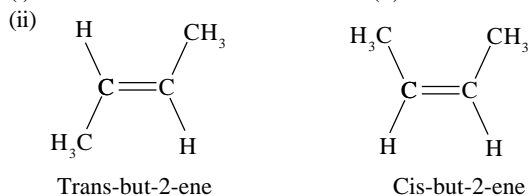


- Explain why chiral molecules are said to have 'optical' isomers.
- What is a racemic mixture?

## Answers.

- (a)

- (i) Lack of rotation about the double ( $\pi$ ) bond.



- (a)  $CH_3CH=CH_2$   
 (b)  $CH_3CH_2CH_2CHOHCH_3$   
 (c)  $CHI_3$   
 (d)  $CH_3CCl_2CH=CBrCHOHCH_3$
- (a) A species with an unpaired electron.  
 (b) An acceptor of a lone pair of electrons (to form a new covalent bond).  
 (c) When an atom or group in a molecule is replaced by another atom or group.  
 (d) When water reacts with a molecule, which is split into 2 parts.
- (a) (i)  $CH_2=CH_2 + H_2 \rightarrow CH_3CH_3$   
 Conditions: Heat over a nickel catalyst.  
 (ii)  $CH_3CH_3 + Cl_2 \rightarrow CH_3CH_2Cl + HCl$   
 Conditions: UV light.  
 (b) Free radical substitution.
- (a) (i)  $CH_3CH=CH_2 + HBr \rightarrow CH_3CHBrCH_3$   
 Conditions: Room temperature.  
 (ii)  $CH_3CHBrCH_3 + KCN \rightarrow CH_3CHCNCH_3 + KBr$   
 Conditions: KCN in water/ethanol, heat under reflux.  
 (b) Nucleophilic substitution.
- (a)
- (b) A single optical isomer has the ability to rotate plane-polarised monochromatic light.
- (c) A solution containing equal amounts of two optical isomers. A racemic mixture will show no rotation of plane-polarised light as the effect of the two optical isomers cancel each other out.

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