FACTFILE:
GCE CHEMISTRY

4.6 ISOMERISM

Rewarding Learning

Learning Outcomes

Students should be able to:

4.6.1 recognise that structural isomerism can exist between molecules which belong to different families of compounds;

4.6.2 recall that asymmetric (chiral) centres give rise to optical isomers which exist as non-superimposable mirror images;

4.6.3 draw 3D representations of optical isomers;

4.6.4 recall that optical isomers rotate the plane of plane polarised light in opposite directions;

4.6.5 define and understand the term optically active and explain why racemic mixtures are optically inactive;

4.6.6 recognise that drug action may be determined by the stereochemistry of the drug and their receptor sites.

Optical isomerism

Molecules which have the same molecular formula but a different structural formula are known as structural isomers.

Stereoisomers are molecules which have the same structural formula but different 3D spatial arrangements (are non-superimposeable)

There are two types of stereoisomers, E-Z isomers which you met in AS2, and optical isomers.

Optical isomerism occurs in molecules that have an asymmetric carbon atom.

An asymmetric (chiral) centre is an atom which has four different atoms or groups attached.

Optical isomers are molecules which exist as non-superimposable mirror images

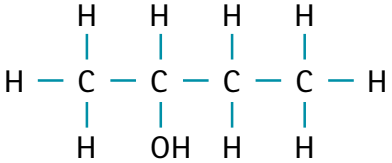
The two optical isomers of a substance are often called enantiomers.

When asked to draw 3D representation of optical isomers, a general method to follow is

- draw the structural formula
- identify the chiral centre
- draw the 3D tetrahedral structure based on the chiral centre and insert the four different groups
- draw a dotted line to represent a mirror, and draw the second isomer by either reflecting the isomer in an imaginary mirror

Example Draw the optical isomers of butan-2-ol.

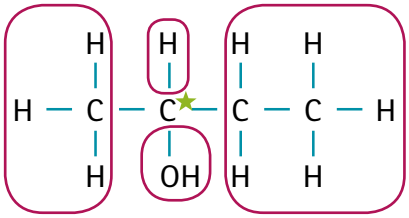
- First draw the structural formula.



- Then identify the chiral centre. The end two carbons have 3 H atoms attached and the third carbon atom from the left has 2 H atoms so these cannot be chiral centres. The second carbon atom has the following groups attached to it:

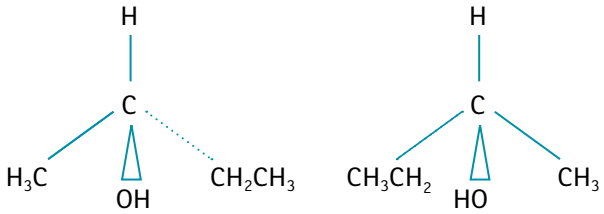
1 CH_3
2 OH
3 H
4 CH_2CH_3

These are four different groups so it is a chiral centre and is marked with an asterisk as shown. It is often useful to circle each of the four groups on the chiral carbon, this helps you remember what groups to place around the tetrahedron.

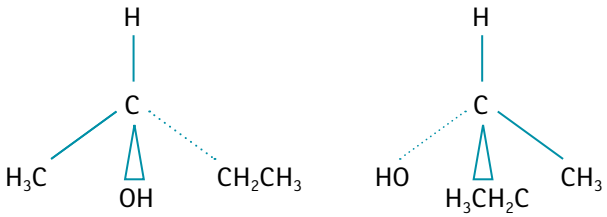


$CH_3\overset{\star}{C}H(OH)CH_2CH_3$

- Draw a 3 dimensional tetrahedral arrangement and insert each of the four different groups at different points on the tetrahedron. Then place a dotted line to represent the mirror, and reflect the image as shown below.



Alternatively to draw the optical isomers you may exchange any two of the groups attached to the chiral centre. An example is shown below.



Make sure when you attach the OH group correctly. The O should be bonded to the carbon.

These isomers cannot be superimposed on each other. They have the same molecular and structural formulae but differ only in the arrangement of groups around the chiral centre.

Optical activity

A light beam consists of waves that vibrate in all planes at right angles to the direction in which the beam is travelling. A polaroid filter only allows light in one plane to pass through it, so when a light beam is passed through a polarising filter all the waves are absorbed apart from the ones vibrating in one particular plane. The light is said to be **plane polarised**.

An optically active substance is one which can rotate the plane of plane polarised light. When a beam of plane polarised light is passed through a solution of one optical isomer, the plane polarised light is rotated either to the left (-) or to the right (+) depending on which isomer is used.

Mixing equal amounts of the same concentration of two enantiomers (optical isomers) gives an **optically inactive mixture** which has no effect on plane polarised light because the two opposite effects cancel out. This mixture of equal amounts of each enantiomer is called a **racemic mixture** or **racemate**. When a chiral compound is synthesised in the laboratory, a mixture of optical isomers is often formed.

Racemic mixture is a 50:50 mixture of two optical isomers.

Stereospecific drugs.

Many commercially available drugs contain molecules with at least one chiral centre, and are often produced as racemic mixtures. It is expensive and difficult to separate enantiomers, and drugs are often sold as racemic mixtures. Drug action depends on the action of one enantiomer in the body. Drugs entering the human body interact with receptors by bonding at specific binding sites. There are many isomers of a particular drug, and each one will have its own effects. For example a racemic mixture of thalidomide was prescribed for morning sickness in the 1960s but the (+) isomer caused deformities in the foetus, while the (-) isomer had negligible side effects.

Hence drug action may be determined by the stereochemistry of the drug and its receptor sites. Nowadays the optical isomers of chiral drugs are isolated and tested separately and drugs which interact specifically with particular receptors are designed, since non specific drugs cause more side effects.

Deformed feet of a baby whose mother took the drug thalidomide during pregnancy

Revision Questions

1 1. Which one of the following does **not** contain an asymmetric centre?

A $CH_3CH(CH_3)CH_2CH_3$

B $CH_3CHClCH_2CH_3$

C $CH_3CH(OH)CH_2CH_3$

D $CH_3CH(NH_2)CH_2CH_3$

2 Which one of the following displays optical isomerism?

A $CH_3CHClCOOH$

B CH_2OHCH_2COOH

C $CH_2OHCOOCH_3$

D CH_2OHCH_2CHO

3 3-hydroxybutanal, $CH_3CH(OH)CH_2CHO$ is optically active.

(i) Explain the term **optically active**.

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(ii) Draw the three-dimensional structures for the two optical isomers of 3-hydroxybutanal.

[2]

(iii) 3-hydroxybutanal may be dehydrated to form but-2-enal. Suggest a structure for but-2-enal.

[1]

4 There are a number of structural isomers of C_4H_9OH however only one has an asymmetric centre and can exist as optical isomer.

a) What is meant by the term asymmetric centre.

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b) Explain in terms of structure the meaning of the term optical isomers.

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..... [2]

c) Draw the displayed formula of the structural isomer of C_4H_9OH which contains an asymmetric centre.

[1]

d) Draw the two optical isomers of the molecules identified in (c)

[2]

e) How can a solution of one optical isomer be distinguished from a solution of another?

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