

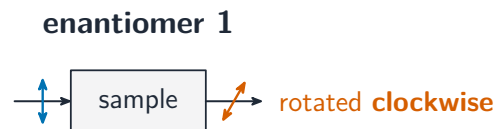
Exercise walk-through

29.4

Isomerism: optical

A-Level Chemistry

Optical isomerism



enantiomer 2 (mirror image)



a 50:50 **racemic mixture** gives no net rotation (the two cancel)

Two **enantiomers** are identical except:

- they rotate **plane polarised light** in opposite directions (**optically active**)
- a **racemic mixture** (50:50) gives no net rotation

Chirality matters in drugs.

Why chirality matters for a drug

A **chiral centre** is a carbon carrying **four different** groups. Its two **enantiomers** are mirror images – and a living body is not symmetric, so they can have **different biological activity**: one active, the other useless or harmful.

- make both and **separate** them – slow and wasteful
- or use a **chiral catalyst** to make only the one you want

Which of these is chiral?

butan-1-ol – no

butan-2-ol – yes: its C2 carries H, OH, CH₃ and C₂H₅

2-methylpropan-2-ol – no, two methyls are the same

Look for one carbon with four **different** groups. Count carefully – two identical branches kill it.

Why chirality matters for drugs

Two enantiomers

A molecule with a **chiral centre** exists as two enantiomers, and they can behave very differently in the body – one may cure while the other does harm.

Separate them

One route: make the **racemic mixture** and then separate it into the two pure enantiomers – slow, and half the product is wasted.

Or make only one

The better route: a **chiral catalyst** builds just the single enantiomer wanted, so nothing has to be thrown away.

Same formula, same bonds, opposite handedness – and a receptor in the body only fits one of them.

New functional groups at A Level

A **functional group** is the reactive part that names the family and fixes how the molecule behaves. Two join the list:

amide

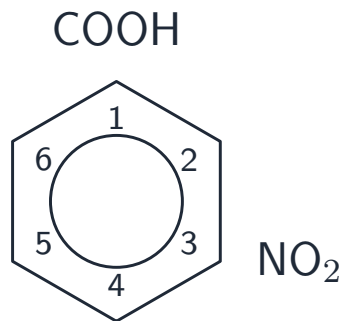
–CONH₂ – a carbonyl bonded straight to nitrogen; the link in proteins and nylon

aromatic

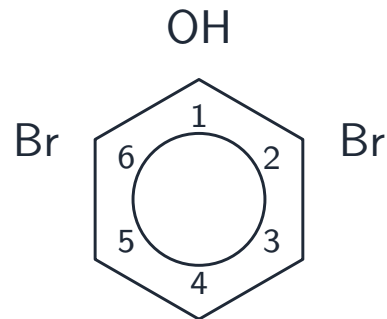
anything built on a benzene ring, with its delocalised electrons and its own chemistry

As before, name the parent chain, then the substituents – and number so the functional group gets the **lowest** locant.

Naming aromatic compounds



3-nitrobenzoic acid



Br
2,4,6-tribromophenol

Number the ring from the principal group (carbon 1); the substituent positions then give the name

Exercises 2.1-2.3

2.1 State what feature a molecule must have to show optical isomerism. [1]

2.2 State why a racemic mixture does not rotate plane-polarised light. [1]

2.3 State the two features that make a molecule optically active. [2]

Exercises 2.1-2.3

2.1 State what feature a molecule must have to show optical isomerism. [1]

2.1

- a chiral centre – a carbon atom bonded to four different groups
-

2.2 State why a racemic mixture does not rotate plane-polarised light. [1]

2.2

- the two enantiomers are present in equal amounts, so their equal and opposite rotations cancel
-

2.3 State the two features that make a molecule optically active. [2]

2.3

- A carbon atom with four different groups attached; the molecule is not superimposable on its mirror image

Exercises 2.4·2.5

2.4 Explain why a racemic mixture shows no optical rotation. [2]

2.5 State one property in which two enantiomers differ, and one in which they are identical. [2]

Exercises 2.4·2.5

2.4 Explain why a racemic mixture shows no optical rotation. [2]

2.4

- It contains equal amounts of the two enantiomers, which rotate the plane of polarised light by equal amounts in opposite directions, so the rotations cancel

2.5 State one property in which two enantiomers differ, and one in which they are identical. [2]

2.5

- They differ in the direction in which they rotate plane-polarised light; they are identical in all ordinary physical properties such as boiling point, and in reactions with non-chiral reagents

Exercises 3.1·3.2

3.1 A chiral carbon atom is bonded to:

[1]

☐

A four identical groups

B two identical and two different groups

C four different groups

D three different groups and one H, with a double bond

3.2 Two enantiomers of a molecule always have the **same**:

[1]

☐

A rotation of plane-polarised light

B boiling point

C effect in the body

D direction of optical rotation

Exercises 3.1·3.2

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- B two identical and two different groups
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3.1 C

- A chiral carbon has four different groups attached

3.2 Two enantiomers of a molecule always have the **same**:

[1]

☐

- A rotation of plane-polarised light
- B boiling point
- C effect in the body
- D direction of optical rotation

3.2 B

- Enantiomers share all physical properties such as boiling point; only the direction of optical rotation and biological activity differ

Exercise 3.3 (a)

3.3 The molecule $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ (lactic acid) is optically active.

(a) Mark the chiral centre and state how many enantiomers it has.

[2]

Exercise 3.3 (a)

3.3 The molecule $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ (lactic acid) is optically active.

(a) Mark the chiral centre and state how many enantiomers it has. [2]

(a)

- the central carbon (bonded to $-\text{OH}$, $-\text{COOH}$, $-\text{CH}_3$ and $-\text{H}$) is the chiral centre; it has 2 enantiomers

Exercise 3.3 (b)

3.3 The molecule $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ (lactic acid) is optically active.

(b) State the two ways in which the enantiomers differ.

[2]

Exercise 3.3 (b)

3.3 The molecule $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ (lactic acid) is optically active.

(b) State the two ways in which the enantiomers differ. [2]

(b)

- they rotate plane-polarised light in opposite directions; they may have different biological effects

Exercise 3.4

3.4 Explain why drug manufacturers often want a single enantiomer rather than a racemic mixture. [2]

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3.4

- the two enantiomers can behave very differently in the body – one may be effective or safe while the other is inactive or harmful; so the maker wants only the beneficial single enantiomer

Exercise 3.5 (a)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(a) Identify the chiral centre in 2-bromobutane and explain your choice. [2]

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(a)

- Carbon 2; it carries $-\text{H}$, $-\text{Br}$, $-\text{CH}_3$ and $-\text{CH}_2\text{CH}_3$, which are four different groups

Exercise 3.5 (b)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(b) Draw the two enantiomers of 2-bromobutane as three-dimensional structures. [2]

Exercise 3.5 (b)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(b) Draw the two enantiomers of 2-bromobutane as three-dimensional structures. [2]

(b)

- Two tetrahedral structures drawn as mirror images, using wedges and dashes, which cannot be superimposed on each other

Exercise 3.5 (c)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(c) A single enantiomer of 2-bromobutane is hydrolysed by an $\text{S}_{\text{N}}2$ mechanism. State what is observed about the optical activity of the product and explain why. [3]

Exercise 3.5 (c)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(c) A single enantiomer of 2-bromobutane is hydrolysed by an $\text{S}_{\text{N}}2$ mechanism. State what is observed about the optical activity of the product and explain why. [3]

(c)

- The product is optically active; in $\text{S}_{\text{N}}2$ the hydroxide attacks from the side opposite the bromine, so the configuration is inverted and a single enantiomer of the alcohol is formed rather than a mixture

Exercise 3.5 (d)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(d) A tertiary halogenoalkane hydrolyses by $\text{S}_{\text{N}}1$. Explain why the product is optically inactive. [3]

Exercise 3.5 (d)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(d) A tertiary halogenoalkane hydrolyses by $\text{S}_{\text{N}}1$. Explain why the product is optically inactive. [3]

(d)

- The mechanism goes through a carbocation intermediate which is planar, with the positive carbon having three groups in a plane; the nucleophile attacks either face with equal probability, giving equal amounts of the two enantiomers, so the product is racemic and optically inactive

Exercise 3.5 (e)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(e) HCN is added to butanone. Explain why the hydroxynitrile formed is a racemic mixture. [3]

Exercise 3.5 (e)

3.5 2-bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, is hydrolysed by aqueous sodium hydroxide.

(e) HCN is added to butanone. Explain why the hydroxynitrile formed is a racemic mixture. [3]

(e)

- The carbonyl carbon in butanone is planar; the cyanide ion attacks from either face with equal probability, giving equal amounts of the two enantiomers of the hydroxynitrile, whose rotations cancel