Optical isomerism

AQA 7405 · A level

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. Spot a chiral carbon

In each alcohol, examine the carbon bonded to OH. Decide whether it is chiral. A is $CH_3CH(OH)CH_3$. B is $CH_3CH(OH)CH_2CH_3$. Give the groups that make the distinction.

2. Connectivity and arrangement

A student calls two non-superimposable mirror images structural isomers because their diagrams look different. Correct the student by comparing the connectivity and three-dimensional arrangements.

3. Draw both mirror images

Draw the two enantiomers of butan-2-ol, $CH_3CH(OH)CH_2CH_3$, using a solid wedge and a dashed wedge in each diagram. Show the four groups bonded to the chiral carbon.

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4. Change the branching

Compare optical isomerism in 2-methylbutane, $CH_3CH(CH_3)CH_2CH_3$, and 3-methylhexane, $CH_3CH_2CH(CH_3)CH_2CH_2CH_3$. Focus on the carbon at the branch point.

5. Compare optical rotation

At the same concentration and path length, one enantiomer rotates plane-polarised light by +12°. Predict the rotation for the other enantiomer and for an equal-mole mixture of the two.

6. Two products from one carbonyl compound

Ethanal reacts with cyanide ions in an achiral environment to form a hydroxynitrile. Identify any new chiral atom and its groups. Explain whether the product is a single enantiomer or a mixture.

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7. Check the whole groups

A student says $CH_3CH(Br)CH(CH_3)_2$ cannot be chiral because three groups on the Br-bearing carbon contain carbon. Assess the claim and name the four groups on that carbon.

8. What does zero rotation tell you?

A liquid shows no overall optical rotation. A student concludes that its molecules have no chiral centres. Give a different composition consistent with the observation and explain why it works.

9. Extra challenge · Use optical rotation and mechanism evidence

The pure enantiomers of a hydroxynitrile give readings of +20° and −20° at the same total concentration and path length. A mixture gives +8° under those conditions. Assume the rotations add in proportion to the mole fractions. Calculate the composition.

Explain, using carbonyl geometry, what reading to expect if the same compound was formed from an achiral aldehyde with cyanide in an achiral environment.

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Worked answers

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1. Spot a chiral carbon

A has two CH_3 groups at that carbon. B has four different groups, H, OH, CH_3 and CH_2CH_3, so its OH-bearing carbon is chiral.

2. Connectivity and arrangement

The molecules are enantiomers, a pair of stereoisomers. The atoms are bonded in the same order, with different arrangements in space.

3. Draw both mirror images

In one diagram, put ordinary bonds to CH_3 above left and CH_2CH_3 above right. Below the centre, put OH on a solid wedge and H on a dashed wedge.

Keep the ordinary bonds in place for the second diagram. Swap OH and H between the wedges to reverse the three-dimensional arrangement.

4. Change the branching

The branch carbon in 2-methylbutane has two methyl groups. In 3-methylhexane the branch carbon has H, methyl, ethyl and propyl groups, so it is chiral.

5. Compare optical rotation

The other enantiomer gives −12° under the same measurement conditions. In an equal-mole mixture the two rotations cancel, giving 0°. This mixture is racemic.

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Worked answers

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6. Two products from one carbonyl compound

The former carbonyl carbon now has four different groups: CH_3, H, OH and C≡N.

The carbonyl group is planar. CN^- can attack either face with equal probability in an achiral environment. The two enantiomers form in equal amounts, giving a racemic mixture.

7. Check the whole groups

The groups are H, Br, CH_3 and $CH(CH_3)_2$. Compare whole attached groups, so methyl and isopropyl count as different. The Br-bearing carbon is chiral.

8. What does zero rotation tell you?

An equimolar mixture of two enantiomers would also give zero rotation. Both enantiomers contain a chiral centre, and their rotations have equal magnitudes in opposite directions. The rotations cancel.

9. Extra challenge · Use optical rotation and mechanism evidence

If f is the fraction of the positive enantiomer, $20f - 20(1 - f) = 8$. This gives $f = 0.70$. The mixture is 70% positive and 30% negative enantiomer.

Cyanide can attack either face of the planar C=O with equal probability in an achiral environment. The hydroxynitrile is produced as a racemic mixture. The equal and opposite rotations give 0°.

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