# InkChemistry

ANSWER BOOK

# Optical isomerism

Carbonyls and carboxylic acids · Unit C20

AQA 3.3.7 · OCR A 6.2.2

17 questions · 55 marks

NAVY EDITION

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## SECTION A · Short, 1 to 2 marks

**A1** OP-Q3

**B1** the chiral centre is carbon 2, the CH carbon bonded to the methyl branch. **B1** its four groups are H, $CH_3$, $CH_2CH_3$ and $CH_2OH$, which are all different. [2]

**A2** OP-Q7

**B1** carbon 3 is bonded to two ethyl groups, so it does not carry four different groups. **B1** every other carbon carries at least two hydrogen atoms, so the molecule has no chiral centre. [2]

## SECTION B · Standard, 3 to 5 marks

**B1** OP-Q6

**B1** the carbonyl group in ethanal is planar, with three groups around the carbon at 120°. **B1** the cyanide ion can attack the carbonyl carbon from above or below the plane with equal probability. **B1** attack from the two faces gives the two enantiomers, so they form in equal amounts as a racemic mixture. **B1** the equal and opposite rotations of the two enantiomers cancel, so the mixture is optically inactive. [4]

**B2** OP-Q10

**B1** butanone gives butan-2-ol, $CH_3CH(OH)CH_2CH_3$. **B1** pentan-3-one gives 2-ethyl-2-hydroxybutanenitrile, $CH_3CH_2C(OH)(CN)CH_2CH_3$. **B1** butan-2-ol is chiral, but hydride attacks the planar C=O equally from either face, so the racemate does not rotate the light. **B1** the nitrile's central carbon carries two ethyl groups, so it is not chiral and cannot rotate the light. [4]

**B3** OP-Q17

**B1** thalidomide was sold as a racemate, and one enantiomer is a sedative while the other causes fetal limb defects. **B1** selling one enantiomer would have avoided giving the harmful enantiomer directly. **B1** however, the two enantiomers interconvert in the body, so the racemate forms again from either one. **B1** so the claim is not supported: the harmful enantiomer would still have been present and the harm would not have been avoided. [4]

**B4** OP-Q2

**B1** a chiral centre is a carbon atom bonded to four different atoms or groups of atoms. **B1** enantiomers are stereoisomers that are non-superimposable mirror images of each other; reject 'mirror images' alone. **B1** they rotate the plane of plane-polarised light by equal amounts in opposite directions; reject 'bend' or 'reflect'. [3]

**B5** OP-Q4

**B1** there are two chiral centres. **B1** carbon 2 is bonded to H, $NH_2$, COOH and the $CH(CH_3)CH_2CH_3$ group. **B1** carbon 3 is bonded to H, $CH_3$, $CH_2CH_3$ and the $CH(NH_2)COOH$ group. [3]

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**B6** OP-Q8 — [3]

**B1** each enantiomer drawn as a tetrahedral carbon with two bonds in the plane of the paper, one solid wedge towards the viewer and one dashed wedge away. **B1** the four groups on the chiral carbon are H, Br, $CH_3$ and $C_2H_5$, with the asterisk on that carbon. **B1** the second structure is the mirror image of the first; two flat structures at 90° score zero.

**B7** OP-Q9 — [3]

**B1** plane-polarised light is passed through a solution of the sample in a tube. **B1** the analyser is turned until the light passing through is brightest again, and the angle of rotation is read. **B1** a single enantiomer rotates the plane, while a racemic mixture gives no rotation.

**B8** OP-Q11 — [3]

**B1** they have identical melting points, boiling points and densities, because their bonds are identical. **B1** they react identically with achiral reagents such as sodium carbonate or ethanol. **B1** they differ in rotating plane-polarised light in opposite directions, and may differ in their reactions with chiral molecules such as enzymes.

**B9** OP-Q12 — [3]

**M1** the 25% of (-) cancels the rotation of 25% of (+), so the racemic part is 50% of the sample. **M1** the excess of (+) is 75 - 25 = 50%, so rotation = 0.50 × (+12.0°). **A1** rotation = +6.0°; the sign is required.

**B10** OP-Q13 — [3]

**M1** the excess of (-) over (+) is 6.0 ÷ 15.0 × 100 = 40%. **M1** the remaining 60% is racemic, so it contains 30% of each enantiomer. **A1** 70% of the (-) enantiomer and 30% of the (+) enantiomer; error carried forward from M1.

**B11** OP-Q14 — [3]

**B1** only one enantiomer may fit the chiral receptor or enzyme, so the other enantiomer is inactive. **B1** the other enantiomer may have harmful side effects, as one enantiomer of thalidomide does. **B1** a smaller dose of the single active enantiomer gives the same effect, and it may act faster.

**B12** OP-Q18 — [3]

**B1** in SN2 the hydroxide ion attacks the carbon from the side opposite the bromine, in a single step. **B1** so every molecule undergoes inversion of configuration in the same way and only one enantiomer of the alcohol forms. **B1** the product is a single enantiomer, not a racemate, so it is optically active.

**B13** OP-Q19 — [3]

**B1** it is a tertiary halogenoalkane, so it reacts by SN1, with the C–Br bond breaking first to give a carbocation. **B1** the carbocation is planar, so the hydroxide ion attacks either face with equal probability. **B1** 3-methylhexan-3-ol is formed as a racemic mixture, whose equal and opposite rotations cancel.

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**B14** OP-Q20 **M1** the excess of (+) over (-) is 4.0 ÷ 16.0 × 100 = 25%, which is the part formed by SN2 with inversion. **M1** the remainder of the product is racemic, which is the part formed by SN1 through the planar carbocation. **A1** 100 - 25 = 75% of the product formed by SN1, to 2 significant figures. [3]

## SECTION C · Long, 6 marks or more

**C1** OP-Q21 **Indicative content** [6]

**B1** carbon 2 of $CH_3CH(OH)COOH$ is bonded to four different groups, H, OH, $CH_3$ and COOH, so it is a chiral centre. **B1** the molecule exists as two enantiomers, non-superimposable mirror images that differ only in the arrangement in space. **B1** the enantiomers have identical physical and chemical properties with achiral reagents, so ordinary tests do not separate them. **B1** they rotate the plane of plane-polarised light by equal amounts in opposite directions, measured with a polarimeter. **B1** the laboratory route adds cyanide to the planar carbonyl of ethanal from either face equally, giving a racemate whose rotations cancel. **B1** the enzyme in muscle has a chiral active site that exposes only one face of the substrate, so a single enantiomer forms and rotates the light.

**Levels**

**Level 3 (5–6 marks)** the chiral centre is identified with its four groups, the enantiomers are described as non-superimposable mirror images, the polarimeter test is given, and both sources are explained: attack on either face of the planar carbonyl giving a racemate in the laboratory, and the chiral active site of the enzyme giving one enantiomer.

**Level 2 (3–4 marks)** the chiral centre and the enantiomers are described and the polarimeter given; the racemate from ethanal or the single enantiomer from the enzyme is explained only in part.

**Level 1 (1–2 marks)** a chiral carbon or mirror-image isomers are mentioned; laboratory lactic acid is commonly said to be inactive because it has no chiral centre.

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