FREE SAMPLE: THE FIRST QUESTION

Question One (22 marks)

(a) The condensed structural formula of a compound is $(CH_3)_3COH$.

(i) Name the compound and state its molecular formula.

(ii) Name the functional group present, and classify the compound.

(iii) Draw (as a condensed formula) and name an isomer of the compound with a different functional group.

(iv) Explain why 2-methylpropan-2-ol has a higher boiling point than ethoxyethane.

[8 marks]

(b) Draw (condensed structural formulae) and name all the alcohols with the molecular formula $C_4H_{10}O$, and classify each as a primary, secondary or tertiary alcohol.

[7 marks]

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(c) Consider the compound butane-2,3-diol.

(i) Identify the chiral carbon atom(s) in butane-2,3-diol, and explain what makes a carbon atom chiral.

(ii) Explain what is meant by ‘optical isomers’ (enantiomers) and describe how two optical isomers of this compound differ in their effect on plane-polarised light.

(iii) State the total number of stereoisomers of butane-2,3-diol and explain why it is not optically active as a whole.

[7 marks]

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THE WORKED ANSWER TO THAT QUESTION

Question 1 (22 marks) [Functional groups and isomers]

(a) The condensed structural formula of a compound is $(CH_3)_3COH$. (i) Name the compound and state its molecular formula. (ii) Name the functional group present, and classify the compound. (iii) Draw (as a condensed formula) and name an isomer of the compound with a different functional group. (iv) Explain why 2-methylpropan-2-ol has a higher boiling point than ethoxyethane.

(a) Answer: (i) 2-methylpropan-2-ol, C4H10O; (ii) alcohol; (iii) ethoxyethane, $CH_3CH_2OCH_2CH_3$; (iv) the alcohol has the stronger intermolecular forces (hydrogen bonding)

- Evidence level: Excellence (identify the functional group from the arrangement of atoms, then use the structure to explain the properties).
- (i) The compound is 2-methylpropan-2-ol; its molecular formula is C4H10O.
- (ii) It is an alcohol: the hydroxyl group –OH; the carbon bonded to OH is attached to three other carbon(s), so it is a tertiary alcohol.
- (iii) An isomer with a different functional group is ethoxyethane, $CH_3CH_2OCH_2CH_3$ (ether), which has the same molecular formula C4H10O.
- Achievement: The alcohol has a higher boiling point than its ether isomer.
- Merit: Links to the forces: the alcohol contains an O–H group so can form hydrogen bonds between molecules; the ether cannot.
- Excellence: Full explanation: alcohol molecules form strong hydrogen bonds between the O–H of one molecule and the lone pair on the O of another; ethers have polar C–O bonds but no hydrogen attached to oxygen, so they have only weaker dipole–dipole and dispersion forces. More energy is needed to overcome hydrogen bonds, so the alcohol has the higher boiling point.

> **KEY TAKEAWAY**
> Functional groups: name by the longest chain and suffix; isomers share a molecular formula but not a structure. Hydrogen bonding needs an H bonded to O or N, so acids and alcohols boil higher than their isomers.

(b) Draw (condensed structural formulae) and name all the alcohols with the molecular formula $C_4H_{10}O$, and classify each as a primary, secondary or tertiary alcohol.

(b) Answer: 7 isomers (butan-1-ol; butan-2-ol; 2-methylpropan-1-ol; 2-methylpropan-2-ol; ethoxyethane; 1-methoxypropane; 2-methoxypropane)

- Evidence level: Excellence (work systematically through the carbon skeletons and positions of the functional group, avoiding repeats).
- The 4 alcohols are: butan-1-ol ($CH_3CH_2CH_2CH_2OH$); butan-2-ol ($CH_3CH_2CH(OH)CH_3$); 2-methylpropan-1-ol ($(CH_3)_2CHCH_2OH$); 2-methylpropan-2-ol ($(CH_3)_3COH$).
- The 3 ethers are: ethoxyethane ($CH_3CH_2OCH_2CH_3$); 1-methoxypropane ($CH_3OCH_2CH_2CH_3$); 2-methoxypropane ($CH_3OCH(CH_3)_2$).
- Classification: butan-1-ol – primary; butan-2-ol – secondary; 2-methylpropan-1-ol – primary; 2-methylpropan-2-ol – tertiary.
- Achievement: Defines structural isomers as compounds with the same molecular formula but different structural formulae.
- Merit: Gives an example from the answer.

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• Excellence: Full answer: structural isomers have the same molecular formula but different arrangements of atoms – the atoms are bonded together in a different order (different carbon chain, different position of the functional group, or a different functional group); chain, position and functional-group isomers appear above.

KEY TAKEAWAY

Isomers: same molecular formula, different structure. Work systematically: first the unbranched chain with the group at each position, then the branched chains; check each is different before counting.

(c) Consider the compound butane-2,3-diol. (i) Identify the chiral carbon atom(s) in butane-2,3-diol, and explain what makes a carbon atom chiral. (ii) Explain what is meant by 'optical isomers' (enantiomers) and describe how two optical isomers of this compound differ in their effect on plane-polarised light. (iii) State the total number of stereoisomers of butane-2,3-diol and explain why it is not optically active as a whole.

(c) Answer: (i) chiral carbon 2 and 3; (ii) non-superimposable mirror images that rotate polarised light in opposite directions; (iii) 3 stereoisomers

• Evidence level: Excellence (find each carbon bonded to four different groups, then link this to the existence of non-superimposable mirror images).

• (i) Chiral carbon(s): carbon 2 and 3 of the chain – bonded to four different groups/atoms. A chiral carbon is a carbon atom bonded to four different atoms or groups.

• Achievement: (ii) States that optical isomers are mirror images that cannot be superimposed.

• Merit: Links to the effect: one isomer rotates the plane of polarised light clockwise and the other rotates it by the same amount anticlockwise.

• Excellence: Full explanation: a molecule with a chiral carbon exists as two stereoisomers (enantiomers) that are non-superimposable mirror images of each other; they have identical physical properties (melting point, boiling point) but rotate the plane of plane-polarised light by equal amounts in opposite directions, so a 1:1 mixture (racemic mixture) shows no net rotation.

• (iii) There are 3 stereoisomers – the two chiral carbons have identical substituents, so one of the isomers has an internal plane of symmetry (a meso form) and is not optically active even though it has chiral carbons.

KEY TAKEAWAY

Optical isomerism: a carbon bonded to four different groups is chiral; enantiomers are non-superimposable mirror images that rotate polarised light equally in opposite directions; n chiral centres give up to 2^n stereoisomers (fewer with a meso form).

LOS: Functional groups and isomers (91391)

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