MEGA LECTURE · A LEVEL CHEMISTRY

Chapter 13: Basic Concepts in Organic Chemistry

OCR A Level Chemistry A (H432) — Structured Practice Worksheet

SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
3.2.1 Basic concepts: nomenclature, formulae, isomerism, reaction mechanisms	90	1 hour 48 minutes

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Instructions to candidates

- Answer **all** questions in the spaces provided. Show all working in calculations.
- Marks are shown in brackets [ ] at the end of each part.

Question 1 — Naming organic compounds (IUPAC nomenclature) 3.2.1

a. State the IUPAC rule used to select the *parent chain* (root name) when naming a branched alkane. **[1]**

b. Give the IUPAC name of the alkane with structural formula $CH_3CH(CH_3)CH_2CH_3$. **[2]**

c. Give the IUPAC name of the alkane with structural formula $(CH_3)_2CHCH_2C(CH_3)_3$. **[3]**

d. State two IUPAC conventions used when a molecule contains two or more identical substituents on the same parent chain (as in your answer to part (c)). **[2]**

e. Give the IUPAC name of the carboxylic acid $CH_3CH_2CH_2COOH$. **[2]**

Question 1 total: 10 marks

Question 2 — Homologous series and general formulae 3.2.1

a. Define the term *homologous series*. **[2]**

b. State two features, other than sharing a general formula, common to successive members of a homologous series. **[2]**

c. State the general formula of (i) the alkanes, (ii) the alkenes, and (iii) the carboxylic acids. **[3]**

d. Complete the table below, giving the general formula and IUPAC suffix for each functional group. **[3]**

Functional group	General formula	IUPAC suffix
Alcohol		
Halogenoalkane		
Carboxylic acid		

Question 2 total: 10 marks

Question 3 — Types of formula

3.2.1

a. Define *empirical formula*. **[1]**

b. Define *molecular formula*. **[1]**

c. A hydrocarbon has empirical formula CH_2 and a molar mass of 84 g mol^{-1}. Determine its molecular formula. **[2]**

d. Explain the difference between a *displayed formula* and a *skeletal formula*, using butan-1-ol as an example. **[3]**

e. Draw the skeletal formula of propanoic acid in the box below. **[2]**

Skeletal formula of propanoic acid

f. State what the ends and vertices (junctions) of the lines represent in a skeletal formula, and how hydrogen atoms bonded to carbon are shown. **[2]**

Question 3 total: 11 marks

Question 4 — Structural isomerism 3.2.1

a. Define the term *structural isomers*. **[2]**

b. Give the names of the three chain isomers of C_5H_{12}. **[3]**

c. But-1-ene and but-2-ene are structural isomers with molecular formula C_4H_8. State the type of structural isomerism they show, and explain why. **[2]**

d. Propan-1-ol and methoxyethane both have the molecular formula C_3H_8O. State the type of structural isomerism shown, name the homologous series to which each compound belongs, and explain why they belong to different homologous series. **[3]**

e. Explain why, for a given molecular formula, a more highly branched chain isomer generally has a lower boiling point than its straight-chain isomer. **[2]**

Question 4 total: 12 marks

Question 5 — E/Z isomerism and CIP priority rules 3.2.1

a. State the two structural conditions that must both be met for an alkene to show E/Z isomerism. **[2]**

b. Explain, in terms of bonding, why restricted rotation about the C=C double bond makes E/Z isomerism possible. **[2]**

c. State the CIP (Cahn–Ingold–Prelog) priority rule used to decide which of two groups attached to a double-bond carbon has the higher priority. **[2]**

d. For but-2-ene, $CH_3CH{=}CHCH_3$, identify the higher-priority group on each double-bond carbon and use this to explain the difference between the E and Z isomers. **[3]**

e. Explain why 2-methylbut-2-ene, $(CH_3)_2C{=}CHCH_3$, does not show E/Z isomerism. **[2]**

Question 5 total: 11 marks

Question 6 — Classifying reaction mechanisms 3.2.1

a. Define an *addition* reaction. **[1]**

b. Define a *substitution* reaction. **[1]**

c. Define an *elimination* reaction. **[1]**

d. **[3]**

Classify each of the following as addition, substitution or elimination: (i) $CH_2{=}CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$; (ii) $CH_3CH_2Br + NaOH(aq) \rightarrow CH_3CH_2OH + NaBr$; (iii) $CH_3CH_2Br + NaOH(ethanol) \rightarrow CH_2{=}CH_2 + NaBr + H_2O$.

e. Explain, in terms of the number of atoms bonded to carbon, why an addition reaction increases the saturation of a molecule while an elimination reaction decreases it. **[3]**

Question 6 total: 9 marks

Question 7 — Curly arrows and bond fission 3.2.1

a. State what a curly arrow represents in a reaction mechanism. **[2]**

b. Define *homolytic fission* and state the type of species produced. **[2]**

c. Define *heterolytic fission* and state the types of species produced. **[2]**

d. Explain why ultraviolet light causes the Cl–Cl bond in chlorine to undergo homolytic, rather than heterolytic, fission. **[2]**

e. In the box below, use curly arrow notation to show the heterolytic fission of the C–Br bond in bromomethane, CH_3Br, to form a bromide ion. **[2]**

Curly arrow diagram — heterolytic fission of CH_3Br

f. State the difference between a full-headed curly arrow and a half-headed (fish-hook) curly arrow. **[2]**

Question 7 total: 12 marks

Question 8 — Nucleophiles, electrophiles and radicals

3.2.1

a. Define *nucleophile* and give one example. **[2]**

b. Define *electrophile* and give one example. **[2]**

c. Define *free radical*. **[2]**

d. Classify each of the following as a nucleophile, an electrophile, or a free radical: (i) OH^-; (ii) the electrophile generated from Br_2 approaching a C=C bond; (iii) $\bullet CH_3$. **[3]**

Question 8 total: 9 marks

Question 9 — Extended response

Synoptic

Explain, with reference to bonding, mechanism type, and the species involved, why alkenes typically react with electrophiles by an addition mechanism, whereas alkanes typically react with radicals by a substitution mechanism. **[6]**

This question is marked using a level of response.

Question 9 total: 6 marks

PAPER TOTAL: 90 MARKS

MARK SCHEME — Chapter 13: Basic Concepts in Organic Chemistry

Award marks independently unless stated. ECF applies to calculations.

Q1 (a) [1]

- The longest continuous (unbranched) carbon chain, containing the principal functional group, is chosen as the parent chain. (1)

Q1 (b) [2]

- 2-methylbutane (2; award 1 if "methylbutane" is given without the correct locant)

Q1 (c) [3]

- Pentane chosen correctly as the longest chain. (1)
- Correct locants 2,2,4 given to the three methyl substituents. (1)
- 2,2,4-trimethylpentane. (1)

Q1 (d) [2]

- Locants (numbers) are assigned to each substituent, chosen to give the lowest possible set of numbers. (1)
- Multiplying prefixes (di-, tri-, tetra-, etc.) are used to show how many identical substituents are present. (1)

Q1 (e) [2]

- Butanoic acid. (2)

Q2 (a) [2]

- A series of compounds with the same general formula. (1)
- Each successive member differs by CH_2 and the members show similar chemical properties. (1)

Q2 (b) [2]

- Successive members differ in molecular formula by CH_2. (1)
- Members show a gradual trend in physical properties (e.g. boiling point) and have similar chemical properties (same functional group). (1)

Q2 (c) [3]

- (i) C_nH_{2n+2} (1)
- (ii) C_nH_{2n} (1)
- (iii) $C_nH_{2n}O_2$ (1)

Q2 (d) [3]

- Alcohol: $C_nH_{2n+1}OH$, suffix −ol. (1)
- Halogenoalkane: $C_nH_{2n+1}X$, named with halogeno- prefix (no suffix). (1)
- Carboxylic acid: $C_nH_{2n+1}COOH$, suffix −oic acid. (1)

Q3 (a) [1]

- The simplest whole-number ratio of atoms of each element present in a compound. (1)

Q3 (b) [1]

- The actual number of atoms of each element present in one molecule of a compound. (1)

Q3 (c) [2]

- Empirical formula mass of CH_2 = 14; 84 ÷ 14 = 6. (1)
- Molecular formula = C_6H_{12}. (1)

Q3 (d) [3]

- A displayed formula shows every atom and every bond in the molecule drawn out explicitly. (1)
- A skeletal formula omits carbon atoms and hydrogen atoms bonded to carbon, showing only the carbon skeleton as a zig-zag line with other atoms/groups shown explicitly. (1)
- For butan-1-ol, both represent $CH_3CH_2CH_2CH_2OH$, but the skeletal formula is a four-carbon zig-zag chain ending in −OH with no C or H symbols shown on the chain. (1)

Q3 (e) [2]

- Correct carbon skeleton (two-carbon zig-zag) for propanoic acid. (1)
- Correctly shown C=O and −OH at the end carbon (CH_3CH_2COOH). (1)

Q3 (f) [2]

- Each end of a line and each vertex (junction between lines) represents a carbon atom. (1)
- Hydrogen atoms bonded to carbon are not shown — enough are assumed present to give each carbon four bonds in total. (1)

Q4 (a) [2]

- Compounds with the same molecular formula. (1)
- ...but a different structural arrangement of atoms (different structural formula). (1)

Q4 (b) [3]

- Pentane. (1)
- 2-methylbutane. (1)
- 2,2-dimethylpropane. (1)

Q4 (c) [2]

- Position isomerism. (1)
- The carbon skeleton and functional group (C=C) are the same, but the double bond is in a different position along the chain. (1)

Q4 (d) [3]

- Functional group isomerism. (1)
- Propan-1-ol is an alcohol; methoxyethane is an ether. (1)
- They have different functional groups giving different chemical properties, so despite sharing a molecular formula they belong to different homologous series. (1)

Q4 (e) [2]

- Branching makes the molecule more compact/spherical, reducing the surface area of contact between neighbouring molecules. (1)
- This weakens the van der Waals forces between molecules, so less energy is needed to separate them, giving a lower boiling point. (1)

Q5 (a) [2]

- Each carbon atom of the C=C double bond must be attached to two different groups/atoms. (2; 1 mark for each carbon)

Q5 (b) [2]

- The pi bond (sideways overlap of p-orbitals above and below the molecular plane) prevents rotation about the C=C axis without breaking the pi bond. (1)
- This locks the attached groups in fixed positions relative to each other, giving rise to two distinguishable spatial arrangements. (1)

Q5 (c) [2]

- For each carbon of the double bond, the two attached groups are compared by the atomic number of the atom directly attached. (1)
- The group whose attached atom has the higher atomic number is given the higher priority. (1)

Q5 (d) [3]

- On each carbon, CH_3 (carbon) has higher priority than H (hydrogen). (1)
- In the Z-isomer, the two higher-priority CH_3 groups are on the same side of the double bond. (1)
- In the E-isomer, the two higher-priority CH_3 groups are on opposite sides of the double bond. (1)

Q5 (e) [2]

- One of the double-bond carbons, $(CH_3)_2C=$, is attached to two identical CH_3 groups. (1)
- Since this carbon does not have two different groups attached, the condition for E/Z isomerism is not met. (1)

Q6 (a) [1]

- A reaction in which two (or more) molecules combine to form a single product, with no atoms lost. (1)

Q6 (b) [1]

- A reaction in which an atom or group of atoms in a molecule is replaced by a different atom or group. (1)

Q6 (c) [1]

- A reaction in which a small molecule is removed from a larger molecule, often forming a double bond. (1)

Q6 (d) [3]

- (i) Addition. (1)
- (ii) Substitution. (1)
- (iii) Elimination. (1)

Q6 (e) [3]

- Addition reactions convert a double (pi) bond into two single bonds, adding new atoms/groups to the carbons involved. (1)
- Elimination reactions remove atoms/groups from adjacent carbons and form a new pi bond (C=C) between them. (1)
- So addition increases, and elimination decreases, the number of atoms bonded to those carbons (saturation). (1)

Q7 (a) [2]

- A curly arrow represents the movement of a pair of electrons. (1)
- The tail shows where the electron pair starts (a bond or lone pair) and the head shows where it moves to. (1)

Q7 (b) [2]

- Homolytic fission is the breaking of a covalent bond in which each fragment receives one electron from the bonded pair. (1)
- Two radicals (species with an unpaired electron) are formed. (1)

Q7 (c) [2]

- Heterolytic fission is the breaking of a covalent bond in which one fragment receives both electrons from the bonded pair. (1)
- A cation and an anion are formed. (1)

Q7 (d) [2]

- UV light provides energy that is absorbed by the Cl_2 molecule, weakening and breaking the bond. (1)
- The Cl–Cl bond is non-polar (identical atoms), so there is no favoured unequal charge split; the bond therefore splits evenly, each Cl atom taking one electron (homolytic fission). (1)

Q7 (e) [2]

- A full-headed (double-barbed) curly arrow drawn from the C–Br bond. (1)
- Arrowhead pointing to the Br atom, showing formation of Br^- and CH_3^+. (1)

Q7 (f) [2]

- A full-headed arrow (two barbs) shows the movement of a pair of electrons (heterolytic fission). (1)
- A half-headed/fish-hook arrow (one barb) shows the movement of a single electron (homolytic fission). (1)

Q8 (a) [2]

- An electron-pair donor — a species with a lone pair (or region of high electron density) attracted to an electron-deficient atom. (1)
- Example: OH^-, CN^-, NH_3, H_2O (any one). (1)

Q8 (b) [2]

- An electron-pair acceptor — a species attracted to and accepting a pair of electrons from a region of high electron density. (1)
- Example: Br_2 ($Br^{\delta+}$), H^+, NO_2^+ (any one). (1)

Q8 (c) [2]

- A species (atom, molecule or ion) with an unpaired (single) electron. (1)
- Shown with a dot (•) representing the unpaired electron; typically highly reactive. (1)

Q8 (d) [3]

- (i) Nucleophile. (1)
- (ii) Electrophile. (1)
- (iii) Free radical. (1)

Q9 [6] — Level of response

- **Level 3 (5–6):** Gives a full and accurate explanation of both mechanisms: correctly links the accessible pi-electron density of alkenes to attraction of electrophiles (electrophilic addition), and the strong, non-polar, unreactive C–H/C–C sigma bonds of alkanes to the need for radical initiation (free-radical substitution).
- **Level 2 (3–4):** Explains one mechanism (alkene or alkane) fully and correctly, with a partial or less complete explanation of the other.
- **Level 1 (1–2):** States that alkenes and alkanes react differently but with limited or generic reasoning; little reference to bonding or mechanism.

Indicative content: *The C=C pi bond in alkenes is a region of high, exposed electron density above and below the plane of the molecule, which readily attracts electrophiles (electron-deficient species) even under mild conditions, allowing alkenes to undergo electrophilic addition reactions relatively easily. In contrast, the C–H and C–C sigma bonds in alkanes are strong, non-polar (or only very weakly polar) and have their electron density shielded along the bond axis between the nuclei, so they are not attractive to nucleophiles, electrophiles, or (under normal conditions) to most reagents at all. Alkanes are therefore generally unreactive except with radicals, since energy (e.g. UV light) is needed to homolytically break a bond and generate an initiating radical, after which free-radical substitution can proceed via chain propagation.*

END OF MARK SCHEME · 90 marks