CrackingCHEM
GCSE | A-LEVEL
UNDERSTAND • APPLY • SUCCEED

AQA CHEMISTRY 7405

INTRODUCTION TO
ORGANIC CHEMISTRY I

FORMULAE • NOMENCLATURE • STRUCTURAL ISOMERISM

SPEC	CRACK IT	TEST IT	DONE WHEN

SPECIFICATION AND STUDENT NOTES

AQA SECTION	YOU WILL MASTER
3.3.1.1	Six formula representations and homologous-series language
3.3.1.1	IUPAC naming and drawing for chains and rings up to six carbons
3.3.1.3	Chain, position and functional-group structural isomerism

BOUNDARY Reaction mechanisms, curly arrows, stereoisomerism, E/Z isomerism and CIP rules belong to Introduction to Organic Chemistry II.

THE. BIG PICTURE

WHY IT MATTERS
Organic questions constantly switch between names, formulae and skeletal structures. Fluency here protects marks in every later organic topic.

YOU WILL MASTER
Six formula types; functional groups; a repeatable naming route; drawing from names; and generating structural isomers without duplicates.

1 REPRESENT

molecular

C_5H_{12}

structural

$CH_3CH(CH_3)CH_2CH_3$

2 NAME

2-methylbutane

3 TEST ISOMERS

C_5H_{12}

- ✓ pentane
- ✓ 2-methylbutane
- ✓ 2,2-dimethylpropane

THE ORGANIC ROUTE REPRESENT → COUNT → CHOOSE THE PARENT → NUMBER → NAME → CHECK. For isomers: fix the molecular formula, change one structural feature at a time, then reject duplicates.

FULL-MARK DEFINITION BANK

TERM	EXAM-READY DEFINITION	EXAMPLE
Hydrocarbon	A compound containing carbon and hydrogen only.	propane, C_3H_8
Functional group	An atom or group of atoms responsible for the characteristic reactions of a compound.	-OH in ethanol
Homologous series	A family of organic compounds with the same functional group and general formula; successive members differ by CH_2.	alkenes
Structural isomers	Compounds with the same molecular formula but different structural formulae.	butane / 2-methylpropane
Empirical formula	The simplest whole-number ratio of atoms of each element in a compound.	$C_4H_8 \rightarrow CH_2$
Molecular formula	The actual number of atoms of each element in one molecule.	but-2-ene: C_4H_8
General formula	An algebraic formula that represents any member of a homologous series.	alkenes: C_nH_{2n}
Structural formula	The minimum detail that shows how the atoms are arranged and bonded in a molecule.	$CH_3CH=CHCH_3$
Displayed formula	A formula showing every atom and every covalent bond in a molecule.	ethyne: H-C≡C-H
Skeletal formula	A formula in which C atoms and H atoms bonded to C are omitted; bonds and all other atoms are shown.	but-1-ene

TEST IT DEFINITIONS

1. Define empirical formula and give an example. 2. Define molecular formula and give an example. 3. State what a displayed formula must show and give an example. **[6 marks]**

DONE WHEN you can move between formula, name and structure without changing the molecule.

1. The language of organic chemistry

SPEC 3.3.1.1 Know the characteristics of a homologous series and recognise functional groups in organic compounds.

CRACK IT Do not treat 'organic compound', 'hydrocarbon', 'functional group' and 'homologous series' as interchangeable terms.

TERM	WHAT IT MEANS	QUICK CHECK
organic chemistry	the chemistry of covalent compounds of carbon	methane and ethanol are organic; CO_2 and carbonates are not treated as organic
hydrocarbon	a compound containing carbon and hydrogen only	propane and propene are hydrocarbons; ethanol is not
functional group	an atom or group of atoms responsible for the characteristic reactions of a compound	C=C in alkenes; -OH in alcohols; -COOH in carboxylic acids
alkyl group	a group formed by removing one H atom from an alkane	methyl = CH_3-, ethyl = C_2H_5-, propyl = C_3H_7-

A homologous series has five connected characteristics

SAME	CHANGES GRADUALLY	STEP BETWEEN MEMBERS
functional group	physical properties such as boiling point	successive members differ by CH_2
general formula	molecular size and intermolecular attraction	relative molecular mass rises by 14
similar chemical properties	state or volatility may change	for example ethane → propane

ALKANE EXAMPLE

Methane CH_4 → ethane C_2H_6 → propane C_3H_8. Each successive member adds CH_2; all fit C_nH_{2n+2}.

ALKENE EXAMPLE

Ethene C_2H_4 → propene C_3H_6 → but-1-ene C_4H_8. Each successive member adds CH_2; all fit C_nH_{2n}.

EXAM TRAP A homologous series does not contain identical compounds. Members share a functional group and general formula, but their carbon-chain lengths differ.

TEST IT 1

1. Define a hydrocarbon. 2. Define a functional group. 3. State four characteristics of a homologous series. 4. Explain why propanone is not a hydrocarbon. 5. Pentane and hexane are successive members: state the formula difference and the increase in M_r. **[9 marks]**

DONE WHEN you can define the core terms, apply all five homologous-series characteristics and compare successive members.

2. Six ways to represent an organic compound

SPEC 3.3.1.1 Organic compounds can be represented by empirical, molecular, general, structural, displayed and skeletal formulae.

CRACK IT The formula type controls what information is shown. Before answering, identify whether the question asks for numbers, connectivity, every bond or the carbon skeleton.

MOLECULAR

C_4H_8

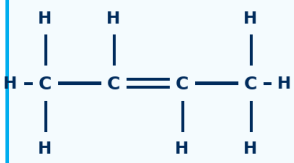
actual numbers of each atom

STRUCTURAL

$CH_3CH{=}CHCH_3$

shows the order of the atoms

DISPLAYED



all 4 C, all 8 H and every bond

SKELETAL

C and C-H omitted; C=C shown

FORMULA	WHAT IT SHOWS	EXAMPLE FOR BUT-2-ENE / ALKENES
empirical	simplest whole-number ratio	CH_2
molecular	actual number of each atom	C_4H_8
general	pattern for a homologous series	alkenes: C_nH_{2n}
structural	order in which atoms are bonded	$CH_3CH{=}CHCH_3$
displayed	every atom and every bond	all C-H, C-C and C=C bonds
skeletal	carbon skeleton; C and C-H omitted	line-angle representation with C=C

TEST IT 2

Pent-1-ene has structural formula $CH_2{=}CHCH_2CH_2CH_3$. State its molecular formula, its empirical formula and the general formula of its homologous series. **[3 marks]**

.....

.....

.....

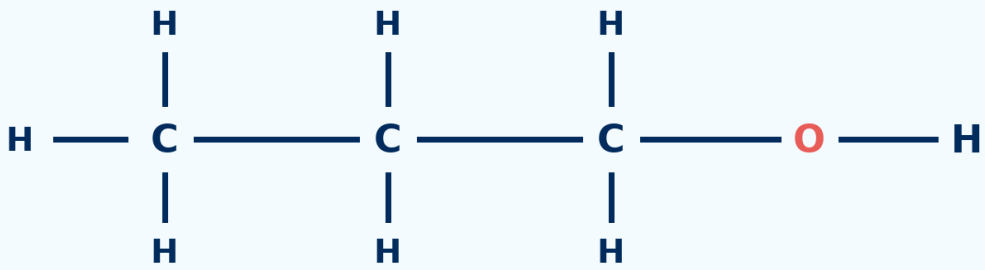
DONE WHEN you select the correct representation and never confuse molecular, empirical and general formulae.

3. Displayed and structural formulae

SPEC 3.3.1.1 Draw structural and displayed formulae for given organic compounds.

CRACK IT Displayed means every atom and every bond. Structural means the atom order is clear, but individual C-H bonds may be grouped.

DISPLAYED FORMULA: propan-1-ol



DISPLAYED CHECK

Every carbon must have four bonds. Oxygen normally has two bonds. Hydrogen has one bond. Count around every atom before moving on.

STRUCTURAL CHECK

Group atoms around each carbon in sequence: $CH_3CH_2CH_2OH$. Brackets show a branch or attached group: $CH_3CH(OH)CH_3$.

WORKED EXAMPLE **Write two formulae for propan-1-ol**

Count the displayed atoms: 3 carbon, 8 hydrogen and 1 oxygen, so molecular formula = C_3H_8O.
Read along the carbon chain and include the O-H group: structural formula = $CH_3CH_2CH_2OH$.

VALENCY TRAP A carbon with only three single bonds is missing a bond. A carbon shown with five bonds is impossible in the neutral structures used here.

TEST IT 3

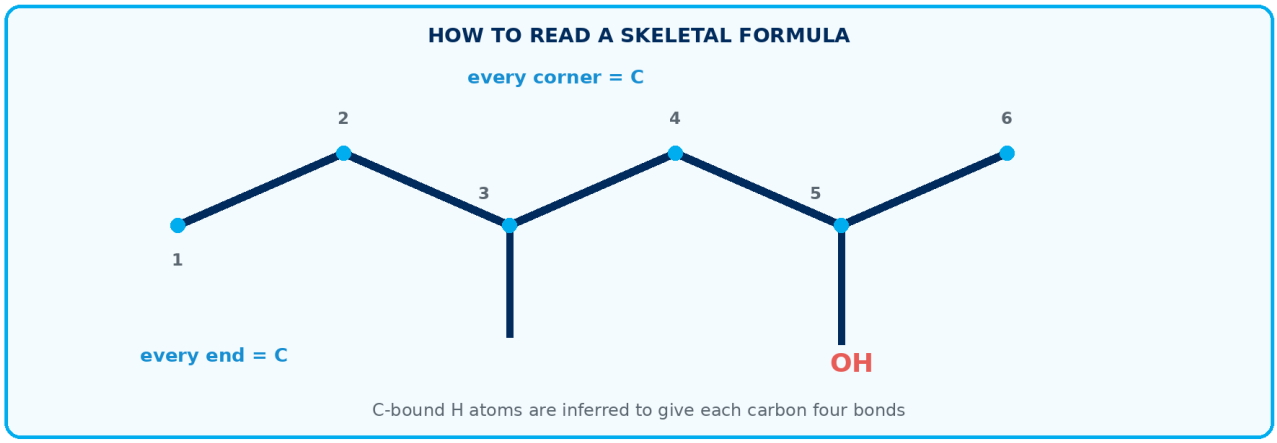
Chloromethane has structural formula CH_3Cl. Draw its displayed formula, state its molecular formula and state how many C-H bonds it contains. **[3 marks]**

DONE WHEN you can count atoms and verify carbon, oxygen and hydrogen valencies before accepting a structure.

4. Skeletal formulae: make the invisible atoms visible

SPEC 3.3.1.1 Interpret and draw skeletal formulae for organic compounds.

CRACK IT Every unlabelled line end and every vertex represents a carbon. Hydrogens attached to carbon are omitted; other atoms and their hydrogens are shown.



SKELETAL FEATURE	READ IT AS
unlabelled line end	a carbon atom
corner / vertex	a carbon atom
one line	one covalent bond
two or three parallel lines	C=C or C≡C
O, N, Cl, Br or other label	the named atom is present and must be counted
missing H on carbon	add enough H to give that carbon four bonds

COMMON LOST MARK A zigzag with five line segments contains six carbons, not five. Count ends and corners, not lines.

TEST IT 4

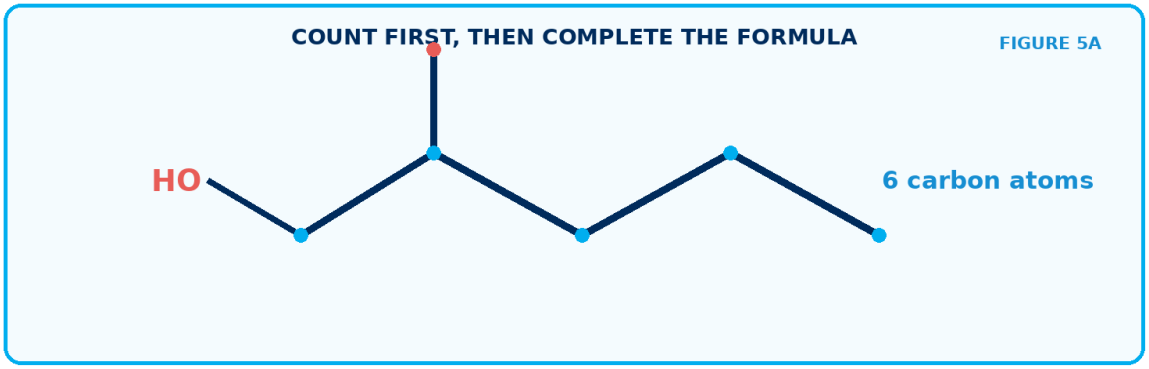
A skeletal structure contains seven carbon positions, one C≡C bond and a terminal Cl atom. Explain how the carbon atoms are counted, which hydrogen atoms are omitted, how the triple bond is shown and whether the Cl may be omitted. **[4 marks]**

DONE WHEN you count every end and vertex and know exactly which atoms may be omitted.

5. Convert skeletal formulae without guessing

SPEC 3.3.1.1 Move accurately between structural, displayed and skeletal formulae.

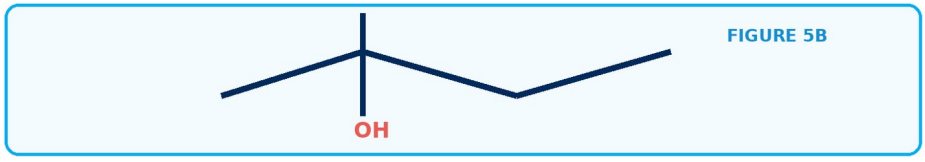
CRACK IT Use a fixed route: count carbon atoms → mark multiple bonds and heteroatoms → complete each carbon to four bonds → total every atom.



WORKED EXAMPLE **Find the molecular formula of the skeletal structure**

Carbon: five atoms in the main chain plus one methyl branch = 6 C.
Oxygen: one O in the -OH group = 1 O.
Hydrogen: complete every carbon to four bonds and include the O-H hydrogen = 14 H.
Final molecular formula: $C_6H_{14}O$. Structural formula: $HOCH_2CH(CH_3)CH_2CH_2CH_3$.

SENSE CHECK A saturated open-chain monohydric alcohol has formula $C_nH_{2n+2}O$. For n = 6, H = 14, which agrees with the count.



TEST IT 5

For the skeletal structure in Figure 5B: state its molecular formula, write a structural formula, identify the longest carbon chain, state the -OH locant and give the IUPAC name. **[6 marks]**

DONE WHEN you can reconstruct every omitted carbon-bound hydrogen and verify the final molecular formula.

6. Recognise the functional group before naming

SPEC 3.3.1.1 Use functional groups and IUPAC rules when naming and drawing organic compounds.

CRACK IT Circle the functional group first. It usually supplies the suffix and controls the direction in which the parent chain is numbered.

ALKENE

C=C

-ene

propene

HALOALKANE

C-X

fluoro-/chloro-/bromo-/iodo-

1-bromopropane

ALCOHOL

-OH

-ol

propan-1-ol

ALDEHYDE

-al

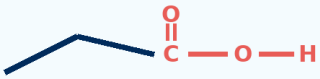
propanal

KETONE

-one

propanone

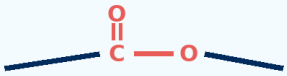
CARBOXYLIC ACID



-oic acid

propanoic acid

ESTER



alkyl alkanoate

methyl ethanoate

AMINE

$-NH_2$

-amine

propan-1-amine

NITRILE

$-C\equiv N$

-nitrile

propanenitrile

SCOPE These are naming and recognition signals only. Their detailed reactions, tests and mechanisms are taught in the later homologous-series units.

TEST IT 6

Identify the functional group and homologous series in each: $CH_2=C(CH_3)CH_2CH_3$; $CH_3CH_2CH_2Cl$; $CH_3CH(OH)CH_2CH_3$; CH_3CHO; $CH_3CH_2COCH_3$; $CH_3CH_2CH_2CH_2COOH$; $CH_3COOCH_2CH_2CH_3$; $CH_3CH_2CH_2CH_2CN$. **[8 marks]**

DONE WHEN you locate the functional group before trying to choose a suffix, prefix or numbering direction.

7. The repeatable AQA naming method

SPEC 3.3.1.1 Apply IUPAC rules to name and draw chains and rings containing up to six carbon atoms.

CRACK IT Build the name in a fixed order. Do not name by staring at the whole molecule and hoping it looks familiar.

CARBONS	ROOT	ALKANE	ALKYL GROUP
1	meth-	methane	methyl
2	eth-	ethane	ethyl
3	prop-	propane	propyl
4	but-	butane	butyl
5	pent-	pentane	pentyl
6	hex-	hexane	hexyl

NAME IT IN SIX MOVES

STEP	ACTION	CHECK
1	find the principal functional group	this usually supplies the suffix
2	choose the longest parent chain containing it	count every carbon once
3	number from the correct end	give the suffix group or multiple bond the lowest locant
4	identify and locate substituents	methyl, ethyl, bromo, chloro...
5	alphabetise different substituents	ignore di-, tri- and tetra- when alphabetising
6	assemble and punctuation-check	commas between numbers; hyphens between numbers and words

PUNCTUATION 2,3-dimethylbutane has a comma between 2 and 3, hyphens around the locants and no spaces.

TEST IT 7

Name $CH_3CH_2CH(CH_2CH_3)CH_2CH_3$ and $CH_3C(CH_3)_2CH_2CH_2CH_3$. Then state the root used for a six-carbon parent chain and the name of a two-carbon substituent. **[4 marks]**

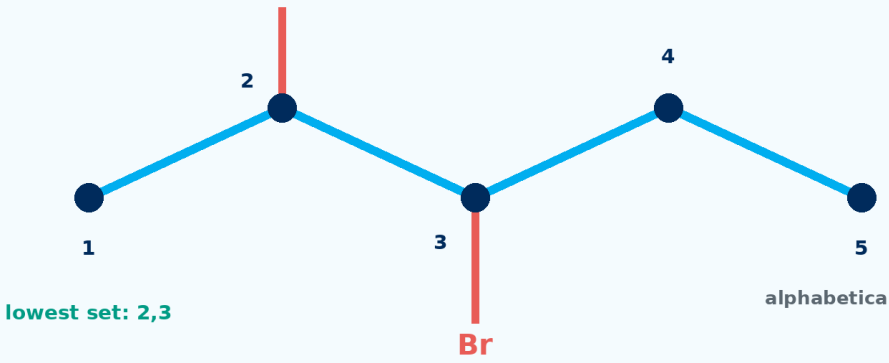
DONE WHEN you can build a name from parent, locants, substituents and suffix with correct punctuation.

8. Longest chain, lowest locants and substituents

SPEC 3.3.1.1 Select the correct parent chain, number it and name substituted organic compounds systematically.

CRACK IT The parent must be a continuous carbon chain. It does not have to be drawn horizontally, and the chain cannot jump across a branch.

NAME THE PARENT FIRST: 3-bromo-2-methylpentane



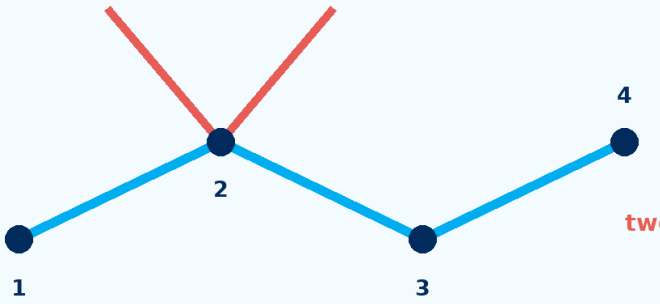
lowest set: 2,3

alphabetical: bromo before methyl

WORKED EXAMPLE **Name the structure**

Longest continuous chain = five carbons, so the parent is pentane.
Numbering left to right gives substituent locants 2 and 3; the other direction gives 3 and 4.
Substituents are bromo at C-3 and methyl at C-2. Alphabetical order gives bromo before methyl.
Final name: 3-bromo-2-methylpentane.

2,2-dimethylbutane: the parent is the longest continuous chain



two methyl groups
both on C-2

EXAM TRAP Never use 3-methylbutane. Reversing the numbering gives the lower locant: 2-methylbutane.

TEST IT 8

For $CH_3CH(CH_3)CH(CH_2CH_3)CH_2CH_2CH_3$: identify the longest parent chain, compare the substituent locant sets from both ends, identify the substituents and give the complete IUPAC name. **[5 marks]**

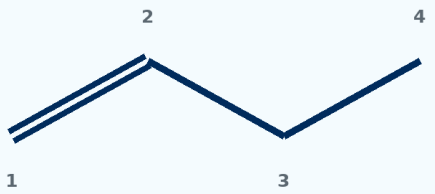
DONE WHEN you find a genuine longest chain, compare both numbering directions and order substituents correctly.

9. Give the important feature the lowest locant

SPEC 3.3.1.1 Use position numbers when naming compounds containing multiple bonds or functional groups.

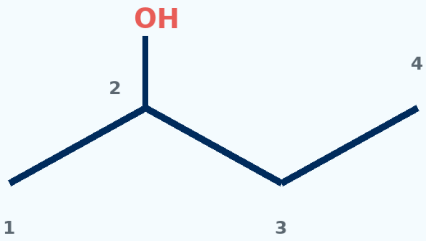
CRACK IT For the examples in this pack: number to give the suffix functional group the lowest locant; if there is none, give the C=C bond the lowest locant; then consider substituents.

BUT-1-ENE



double bond begins at C-1

BUTAN-2-OL



OH is attached to C-2

FEATURE	LOCANT TELLS YOU	CORRECT PATTERN
C=C	first carbon of the double bond	hex-2-ene
-OH	carbon carrying the hydroxyl group	pentan-2-ol
>C=O	carbonyl carbon in a ketone	pentan-2-one
halogen	carbon carrying F, Cl, Br or I	2-bromobutane

NAME FORMAT Use but-1-ene and butan-2-ol. The position number sits immediately before the part of the name that it locates.

TEST IT 9

Name $CH_3CH{=}CHCH_2CH_3$, $CH_3CH_2CH(OH)CH_2CH_3$ and $CH_3CH_2CHClCH_3$ using exact locants and punctuation. **[3 marks]**

DONE WHEN your numbering gives the suffix group or multiple bond priority over ordinary substituents.

10. Use suffixes without losing carbon atoms

SPEC 3.3.1.1 Apply IUPAC nomenclature to compounds containing the functional groups used in the AQA course.

CRACK IT Some functional-group carbons are part of the parent chain. The aldehyde, carboxylic-acid and nitrile carbons all count.

STRUCTURAL FORMULA	COUNTING POINT	IUPAC NAME
CH_3CH_2CHO	CHO carbon is C-1 and is counted	propanal
CH_3COCH_3	carbonyl carbon is within the chain	propanone
CH_3CH_2COOH	COOH carbon is C-1 and is counted	propanoic acid
CH_3COOCH_3	name O-alkyl first, then alkanoate	methyl ethanoate
$CH_3CH_2CH_2NH_2$	number the carbon carrying NH_2	propan-1-amine
$CH_3CH_2C{\equiv}N$	nitrile carbon is C-1 and is counted	propanenitrile

ALDEHYDE
The -CHO group is terminal. Its carbon is automatically carbon 1, so no locant is normally written before -al.

ESTER
Name the group attached directly to the single-bonded O first, then name the acid-derived part as an alkanoate.

CARBON-COUNT TRAP CH_3CH_2CN has three carbon atoms, not two. The carbon in -C≡N belongs to the parent chain.

TEST IT 10

Name each new compound and identify its functional group: $CH_3CH_2CH_2CHO$; $CH_3CH_2COCH_2CH_3$; $CH_3CH_2CH_2COOH$; $CH_3CH_2COOCH_2CH_3$; $CH_3CH(NH_2)CH_2CH_3$; $CH_3CH_2CH_2C{\equiv}N$. **[6 marks]**

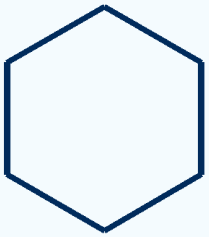
DONE WHEN you count functional-group carbons correctly and choose the required suffix or ester name order.

11. Rings and drawing a structure from its name

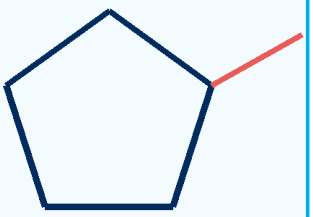
SPEC 3.3.1.1 Name and draw chains and rings containing up to six carbon atoms.

CRACK IT Use cyclo- for a ring parent. A monosubstituted ring needs no position number; with two or more substituents, number for the lowest set of locants.

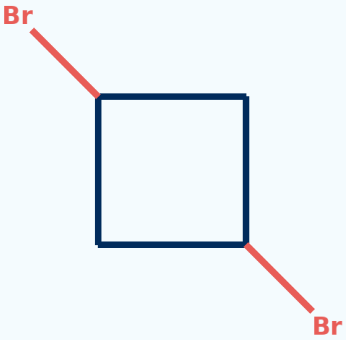
CYCLOHEXANE



METHYLCYCLOPENTANE



1,3-DIBROMOCYCLOBUTANE



DRAW FROM A NAME IN REVERSE

STEP	FOR 3-BROMO-2-METHYLPENTANE
1 draw the parent	draw a five-carbon zigzag
2 number it	mark carbon 1 to carbon 5
3 add substituents	add methyl at C-2 and Br at C-3
4 complete and check	complete carbon valencies; total = six carbons

RING TRAP Do not add a carbon label at every corner of a skeletal ring. The corners already represent carbon atoms.

TEST IT 11

Draw skeletal formulae for 1,2-dimethylcyclobutane, 2-chloro-3-methylbutane and hex-3-ene. Check every locant before finishing. **[6 marks]**

DONE WHEN you can decode a name into parent, numbering, substituents and functional-group position.

12. Structural isomers: same formula, different connectivity

SPEC 3.3.1.3 Define structural isomer and draw chain, position and functional-group isomers.

CRACK IT First prove the molecular formula is identical. Then identify exactly what changes in the structural formula.

CHAIN ISOMERS C_4H_{10}

$CH_3CH_2CH_2CH_3$ ⟷ $CH_3CH(CH_3)CH_3$

carbon skeleton changes

POSITION ISOMERS C_3H_8O

$CH_3CH_2CH_2OH$ ⟷ $CH_3CH(OH)CH_3$

same group, different position

FUNCTIONAL-GROUP ISOMERS C_3H_6O

CH_3CH_2CHO ⟷ CH_3COCH_3

different functional groups

TYPE	WHAT CHANGES	WHAT STAYS THE SAME
chain	arrangement of the carbon skeleton	molecular formula and functional group
position	position of a functional group, multiple bond or substituent	carbon skeleton and functional-group type
functional group	the functional-group type	molecular formula

EXAM TRAP Rotating or redrawing the same connectivity does not make a new structural isomer. Different shape on the page is not enough.

TEST IT 12

Define structural isomers. Classify and justify each new pair: pentane / 2-methylbutane; but-1-ene / but-2-ene; pentanal / pentan-2-one. **[7 marks]**

DONE WHEN you compare molecular and structural formulae before deciding whether two drawings are isomers.

13. Generate all valid isomers without duplicates

SPEC 3.3.1.3 Draw the structures of structural isomers from a given molecular formula.

CRACK IT Work systematically: longest chain first → shorten the parent by one → move one branch through unique positions → increase branching only when necessary.

PENTANE

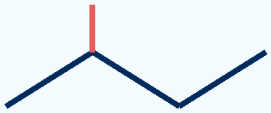
$CH_3CH_2CH_2CH_2CH_3$

molecular formula C_5H_{12}

2-METHYLBUTANE

$CH_3CH(CH_3)CH_2CH_3$

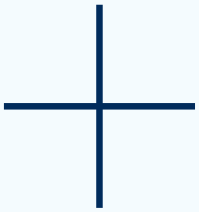
molecular formula C_5H_{12}



2,2-DIMETHYLPROPANE

$C(CH_3)_4$

molecular formula C_5H_{12}



WORKED EXAMPLE Why C_5H_{12} has exactly three chain isomers

Five-carbon parent: pentane gives one straight-chain structure.
Four-carbon parent: one methyl branch gives 2-methylbutane. '3-methylbutane' is the same structure renumbered.
Three-carbon parent: two methyl branches must both be on C-2, giving 2,2-dimethylpropane.
Any other drawing is a rotation, reflection or duplicate of one of these three.

FINAL AUDIT	QUESTION
formula	Does every structure have exactly the stated atoms?
valency	Does every carbon have four bonds?
duplicate	Can one drawing be rotated or renumbered into another?
name	Does each accepted structure have a unique correct IUPAC name?

TEST IT 13

Draw all five structural isomers of C_6H_{14}. Your set must be complete and contain no duplicates. **[5 marks]**

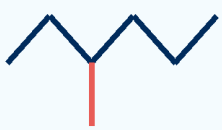
DONE WHEN you can generate an exhaustive isomer set and prove that each drawing is unique and valid.

14. Mixed organic decoding challenge

SPEC 3.3.1.1 + 3.3.1.3 Combine representation, nomenclature, molecular-formula and structural-isomerism skills.

CRACK IT Do not start naming immediately. For every structure: count → identify the functional feature → choose and number the parent → name → formula-check.

A



skeletal

B

$CH_3CH_2CHBrCH_2CH_3$

structural

C

skeletal

D

$CH_3(CH_2)_4CHO$

$CH_3CH_2COCH_2CH_2CH_3$

compare

TEST IT 14

A: give the IUPAC name and molecular formula. B: give the IUPAC name. C: give the IUPAC name and molecular formula. D: name both compounds and state their isomeric relationship. **[8 marks]**

FINAL EXAMINER CHECK Check carbon count, locants, commas, hyphens and suffix spelling. A chemically correct structure can still lose the naming mark through one avoidable numbering error.

DONE WHEN you can decode unfamiliar structures methodically rather than relying on pattern recognition.

FINAL. MASTERY CHECK

THE METHOD REPRESENT → COUNT → CHOOSE THE PARENT → NUMBER → NAME → CHECK. For isomers, change one structural feature at a time and reject duplicates.

	I CAN…	SPEC	CONFIDENCE
☐	distinguish organic compound, hydrocarbon and functional group	3.3.1.1	R / A / G
☐	state the characteristics of a homologous series	3.3.1.1	R / A / G
☐	distinguish all six formula representations	3.3.1.1	R / A / G
☐	draw accurate displayed and structural formulae	3.3.1.1	R / A / G
☐	count carbons in skeletal formulae	3.3.1.1	R / A / G
☐	complete omitted hydrogens using carbon valency	3.3.1.1	R / A / G
☐	identify the functional groups used in the AQA course	3.3.1.1	R / A / G
☐	select the longest valid parent chain	3.3.1.1	R / A / G
☐	number from the correct end	3.3.1.1	R / A / G
☐	use locants, commas and hyphens correctly	3.3.1.1	R / A / G
☐	alphabetise different substituents	3.3.1.1	R / A / G
☐	name and draw chains and rings up to six carbons	3.3.1.1	R / A / G
☐	define structural isomer precisely	3.3.1.3	R / A / G
☐	distinguish chain, position and functional-group isomers	3.3.1.3	R / A / G
☐	generate complete isomer sets without duplicates	3.3.1.3	R / A / G

SEVEN CHECKS WORTH MEMORISING

- A hydrocarbon contains carbon and hydrogen only.
- Every skeletal line end and vertex is a carbon unless another atom is labelled.
- Hydrogens attached to carbon are omitted from skeletal formulae.
- The longest parent must contain the principal suffix group and relevant multiple bond.
- Give the important functional feature the lowest possible locant.
- Structural isomers have the same molecular formula but different structural formulae.
- A different drawing orientation is not a different isomer.

DONE WHEN every box is green and you can complete TEST IT 1-14 without using the notes.

TEST IT. ANSWERS 1-7

MARKING RULE Award one mark for each distinct correct point unless stated otherwise. Equivalent precise chemical wording is acceptable.

D. Definition check Empirical formula: the simplest whole-number ratio of atoms of each element; for example C_4H_8 has empirical formula CH_2. Molecular formula: the actual number of atoms of each element in one molecule; for example but-2-ene is C_4H_8. Displayed formula: shows every atom and every covalent bond; for example ethyne is H-C≡C-H. **[6]**

1. Core language Hydrocarbon: a compound containing carbon and hydrogen only. Functional group: an atom or group of atoms responsible for the characteristic reactions of a compound. Homologous-series points: same functional group; same general formula; similar chemical properties; gradual trend in physical properties; successive members differ by CH_2. Any four series points. Propanone is not a hydrocarbon because it contains oxygen. Pentane → hexane differs by CH_2, so M_r increases by 14. **[9]**

2. Formula types Pent-1-ene, $CH_2{=}CHCH_2CH_2CH_3$, contains C_5H_{10}. Molecular formula = C_5H_{10}; empirical formula = CH_2; alkene general formula = C_nH_{2n}. **[3]**

3. Structural to displayed The displayed formula has one C bonded separately to three H atoms and one Cl atom, with every atom and bond shown. Molecular formula CH_3Cl; three C-H bonds. **[3]**

4. Skeletal rules Count every unlabelled line end and vertex as a carbon atom. Hydrogen atoms bonded to carbon are omitted and inferred from carbon valency. A C≡C bond is shown by three parallel lines. Chlorine is written explicitly as Cl and must not be omitted. **[4]**

5. Figure 5B conversion Molecular formula $C_5H_{12}O$; one valid structural formula is $CH_3C(OH)(CH_3)CH_2CH_3$; longest chain = four carbon atoms; -OH is on carbon 2. The name is 2-methylbutan-2-ol. **[6]**

6. Functional groups $CH_2{=}C(CH_3)CH_2CH_3$: C=C, alkene. $CH_3CH_2CH_2Cl$: C-Cl, haloalkane. $CH_3CH(OH)CH_2CH_3$: -OH, alcohol. CH_3CHO: -CHO, aldehyde. $CH_3CH_2COCH_3$: >C=O, ketone. $CH_3CH_2CH_2CH_2COOH$: -COOH, carboxylic acid. $CH_3COOCH_2CH_2CH_3$: -COO-, ester. $CH_3CH_2CH_2CH_2CN$: -C≡N, nitrile. **[8]**

7. Naming foundations $CH_3CH_2CH(CH_2CH_3)CH_2CH_3$ = 3-ethylpentane. $CH_3C(CH_3)_2CH_2CH_2CH_3$ = 2,2-dimethylpentane. Six-carbon root = hex-. Two-carbon substituent = ethyl. **[4]**

SELF-CHECK: FORMULA LANGUAGE

TYPE	NON-NEGOTIABLE IDEA
molecular	actual number of each type of atom
empirical	simplest whole-number ratio
structural	order in which atoms are bonded
displayed	every atom and every bond
skeletal	C atoms and C-bound H atoms omitted

DONE WHEN you can justify every atom count and every naming decision, not merely copy the final answer.

TEST IT. ANSWERS 8-14

8. Parent and branches The longest parent chain has six carbon atoms, so the parent is hexane. Numbering from the nearer end gives locants 2 and 3; the reverse direction gives 4 and 5. The substituents are ethyl at C-3 and methyl at C-2. Alphabetical order gives 3-ethyl-2-methylhexane. **[5]**

9. Locants $CH_3CH{=}CHCH_2CH_3$ = pent-2-ene. $CH_3CH_2CH(OH)CH_2CH_3$ = pentan-3-ol. $CH_3CH_2CHClCH_3$ = 2-chlorobutane. **[3]**

10. Suffix groups $CH_3CH_2CH_2CHO$: aldehyde, butanal. $CH_3CH_2COCH_2CH_3$: ketone, pentan-3-one. $CH_3CH_2CH_2COOH$: carboxylic acid, butanoic acid. $CH_3CH_2COOCH_2CH_3$: ester, ethyl propanoate. $CH_3CH(NH_2)CH_2CH_3$: amine, butan-2-amine. $CH_3CH_2CH_2C{\equiv}N$: nitrile, butanenitrile. **[6]**

11. Drawing from names Award one mark for each correct parent skeleton and one mark for each complete set of correctly located substituents / double bond: 1,2-dimethylcyclobutane has adjacent methyl groups on a four-carbon ring; 2-chloro-3-methylbutane has a four-carbon chain with Cl at C-2 and methyl at C-3; hex-3-ene has a six-carbon chain with C=C between C-3 and C-4. **[6]**

12. Structural-isomer types Structural isomers are compounds with the same molecular formula but different structural formulae. Pentane / 2-methylbutane: chain isomers because the carbon skeleton changes. But-1-ene / but-2-ene: position isomers because the C=C position changes. Pentanal / pentan-2-one: functional-group isomers because aldehyde changes to ketone. Each pair retains the same molecular formula. **[7]**

13. C_6H_{14} isomers Hexane, $CH_3CH_2CH_2CH_2CH_2CH_3$; 2-methylpentane, $CH_3CH(CH_3)CH_2CH_2CH_3$; 3-methylpentane, $CH_3CH_2CH(CH_3)CH_2CH_3$; 2,2-dimethylbutane, $CH_3C(CH_3)_2CH_2CH_3$; 2,3-dimethylbutane, $CH_3CH(CH_3)CH(CH_3)CH_3$. Award one mark for each unique valid structure. **[5]**

14. Mixed decoding A = 3-methylhexane, C_7H_{16}. B = 3-bromopentane. C = 3-methylbut-1-ene, C_5H_{10}. D = hexanal and hexan-3-one; they are functional-group structural isomers because they have the same molecular formula $C_6H_{12}O$ but different structural formulae / functional groups. **[8]**

FINAL EXAMINER CHECK For every name, verify the parent, numbering direction, locants, alphabetical order, punctuation and suffix. For every structure, verify atom count and carbon valency.

DONE WHEN your answers use exact formula language, valid structures and systematic IUPAC names throughout.