Cambridge IGCSE · Chemistry 0620 · Notes

Organic formulae, functional groups and naming

Read online at **pastopic.com/cambridge/chemistry-0620/notes/organic-formulae-and-naming**

Last checked 30 September 2026

Read first: **Formulae and equations**, **Relative masses and the mole**

What you need to know

By the end of this topic you should be able to:

1. **Draw and read displayed formulae**: a drawing of a molecule that shows every atom and every bond.
2. **Write and use the general formulae** of four homologous series: alkanes $\mathrm{C}_n\mathrm{H}_{2n+2}$, alkenes $\mathrm{C}_n\mathrm{H}_{2n}$, alcohols $\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{OH}$ and carboxylic acids $\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{COOH}$.
3. **Say what a functional group is**: the atom or group of atoms that decides how a homologous series reacts.
4. **State what a homologous series is**: a family of similar compounds with similar chemical properties, because they all have the same functional group.
5. **State what "saturated" means**: every carbon–carbon bond in the molecule is a single bond.
6. **State what "unsaturated" means**: at least one carbon–carbon bond in the molecule is not a single bond (at IGCSE, a C=C double bond).
7. **Name and draw the displayed formulae** of methane, ethane, ethene, ethanol and ethanoic acid, and of the products of the reactions in the later organic topics (for example chloromethane, 1,2-dibromoethane and ethanol).
8. **Tell the type of compound** from a name ending in -ane, -ene, -ol or -oic acid, from a molecular formula, or from a displayed formula.
9. **Extended only: state that a structural formula shows, without any doubt, how the atoms in a molecule are arranged**, for example $\mathrm{CH_2{=}CH_2}$, $\mathrm{CH_3CH_2OH}$ and $\mathrm{CH_3COOCH_3}$.
10. **Extended only: define structural isomers**: compounds with the same molecular formula but different structural formulae, such as butane and methylpropane ($\mathrm{C_4H_{10}}$) or but-1-ene and but-2-ene ($\mathrm{C_4H_8}$).
11. **Extended only: describe the five general characteristics of a homologous series**: the same functional group, the same general formula, a difference of $-\mathrm{CH_2}-$ from one member to the next, a trend in physical properties, and similar chemical properties.
12. **Extended only: name and draw the structural and displayed formulae** of unbranched alkanes, alkenes (including but-1-ene and but-2-ene), alcohols (including propan-1-ol, propan-2-ol, butan-1-ol and butan-2-ol) and carboxylic acids, with up to four carbon atoms.

13. **Extended only: name and draw the displayed formulae of esters** made from unbranched alcohols and carboxylic acids with up to four carbon atoms each.

You also need the meaning of **hydrocarbon** (from the fuels topic, but asked here often): a compound of carbon and hydrogen only. The reactions themselves (combustion, cracking, the bromine test, making ethanol and esters) are in the later organic topics.

Understand it

Organic compounds and hydrocarbons

Organic chemistry is the chemistry of carbon compounds. A carbon atom forms **four** covalent bonds, hydrogen **one** and oxygen **two**. Every correct formula you draw keeps to these numbers, so they are your first check.

A **hydrocarbon** is a **compound** made of **carbon and hydrogen only**. Methane, ethane and ethene are hydrocarbons. Ethanol is not, because its molecules also contain oxygen.

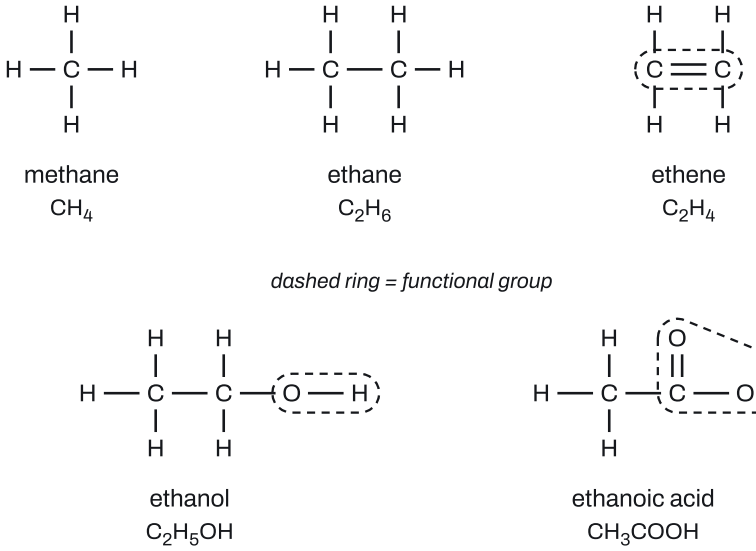
Five kinds of formula

The same substance can be written in several ways. Take ethanol:

Kind of formula	What it shows	Ethanol
Molecular	how many atoms of each element are in one molecule	$\mathrm{C_2H_6O}$
Structural (Extended)	which atoms are joined to which, group by group	$\mathrm{CH_3CH_2OH}$
Displayed	every atom and every bond, drawn out	see the diagram below
General	the pattern every member of the series fits	$\mathrm{C_nH_{2n+1}OH}$
Empirical	the simplest whole-number ratio of atoms	$\mathrm{C_2H_6O}$ (already simplest)

A molecular formula can fit more than one compound, but a structural formula fits only one: $\mathrm{C_2H_6O}$ does not tell you where the O is, while $\mathrm{CH_3CH_2OH}$ does. $\mathrm{C_2H_5OH}$ is also used for ethanol; it keeps the $-\mathrm{OH}$ visible.

In a **displayed formula** each line is one covalent bond and a double line is a double bond. Draw every H, and draw the bond inside $-\mathrm{O}-\mathrm{H}$ too: writing "OH" or "$\mathrm{CH_3}$" as a group is not a displayed formula.



Functional groups and homologous series

A **functional group** is the atom or group of atoms that gives a family of compounds its chemical reactions. Ethene reacts with bromine because of its C=C; ethanoic acid behaves as an acid because of its $-\mathrm{COOH}$.

A **homologous series** is a family of similar compounds with similar chemical properties **because they have the same functional group**. The members of one series:

- have the **same functional group**, so they have **similar chemical properties** (they react in the same ways);
- fit the **same general formula**;
- differ by a $-\mathrm{CH_2}-$ unit from one member to the next, so their M_r goes up by $12 + 2 = 14$ each time;
- show a **trend in physical properties**: as the chain gets longer, the boiling point and melting point increase. The properties are not the same; they change gradually.

Having the same number of carbon atoms does **not** put compounds in one series. Ethane and ethene both have two carbons but are in different series; methane and butane have different numbers of carbons but are in the same series.

The series you need

Series	Functional group	General formula	Name ends in	Members
alkanes	none: only C–C and C–H single bonds	$\mathrm{C}_n\mathrm{H}_{2n+2}$	-ane	methane $\mathrm{CH_4}$, ethane $\mathrm{C_2H_6}$, propane $\mathrm{C_3H_8}$, butane $\mathrm{C_4H_{10}}$
alkenes	C=C	$\mathrm{C}_n\mathrm{H}_{2n}$	-ene	ethene $\mathrm{C_2H_4}$, propene $\mathrm{C_3H_6}$, but-1-ene and but-2-ene $\mathrm{C_4H_8}$

Series	Functional group	General formula	Name ends in	Members
alcohols	$-\mathrm{OH}$	$\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{OH}$	-ol	methanol $\mathrm{CH_3OH}$, ethanol $\mathrm{C_2H_5OH}$, propan-1-ol, propan-2-ol, butan-1-ol, butan-2-ol
carboxylic acids	$-\mathrm{COOH}$	$\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{COOH}$	-oic acid	methanoic acid HCOOH, ethanoic acid $\mathrm{CH_3COOH}$, propanoic acid $\mathrm{C_2H_5COOH}$, butanoic acid $\mathrm{C_3H_7COOH}$
esters (Extended)	$-\mathrm{COO}-$	$\mathrm{C}_n\mathrm{H}_{2n}\mathrm{O}_2$	-oate	ethyl ethanoate $\mathrm{CH_3COOCH_2CH_3}$

Two things to watch in the general formulae:

- **Carboxylic acids:** the carbon in $-\mathrm{COOH}$ is **not** counted in n. Methanoic acid is $n = 0$ (HCOOH); an acid with **four** carbons has $n = 3$: $\mathrm{C_3H_7COOH}$. The first member of the series is methanoic acid (one carbon), but the first alkene is ethene (two carbons: a C=C needs two). So the first members of the alkanes, alkenes, alcohols and carboxylic acids have M_r values of 16, 28, 32 and 46.
- **Written in full**, an alcohol with n carbons is $\mathrm{C}_n\mathrm{H}_{2n+2}\mathrm{O}$ (ethanol is $\mathrm{C_2H_6O}$) and a carboxylic acid with m carbons is $\mathrm{C}_m\mathrm{H}_{2m}\mathrm{O}_2$ (ethanoic acid is $\mathrm{C_2H_4O_2}$). Esters fit $\mathrm{C}_n\mathrm{H}_{2n}\mathrm{O}_2$ too, so an acid and an ester can have the same molecular formula.

Saturated and unsaturated

A compound is **saturated** when **all its carbon–carbon bonds are single bonds**. Alkanes are saturated hydrocarbons. Ethanol and ethanoic acid are saturated too: ethanoic acid has a C=O double bond, but its only carbon–carbon bond is single, and the definition is about **carbon–carbon** bonds.

A compound is **unsaturated** when **at least one carbon–carbon bond is a double bond**, C=C. Alkenes are unsaturated hydrocarbons. For a hydrocarbon, a formula that fits $\mathrm{C}_n\mathrm{H}_{2n}$ (two H fewer than the alkane) means it is an alkene and unsaturated.

Naming compounds

A name has two parts: the **stem** gives the number of carbon atoms in the chain, and the **ending** gives the series.

Carbons	1	2	3	4
Stem	meth-	eth-	prop-	but-

So ethane (2 C, alkane), propene (3 C, alkene), methanol (1 C, alcohol), butanoic acid (4 C, **including** the COOH carbon).

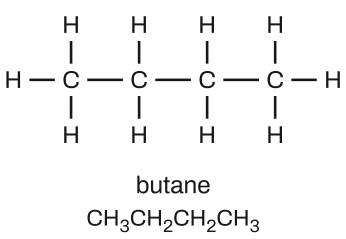
Extended only: position numbers. When the functional group could sit in more than one place, a number says which carbon it is on, counting from the end nearest to it:

- $CH_2{=}CHCH_2CH_3$ is **but-1-ene** (C=C starts at carbon 1); $CH_3CH{=}CHCH_3$ is **but-2-ene**.
- $CH_3CH_2CH_2OH$ is **propan-1-ol**; $CH_3CH(OH)CH_3$ is **propan-2-ol**. In the same way butan-1-ol is $CH_3CH_2CH_2CH_2OH$ and butan-2-ol is $CH_3CH_2CH(OH)CH_3$.
- Ethene, propene, methanol and ethanol need no number (there is only one possible place). Alcohols with three or more carbons always do.
- Brackets in a structural formula show a side group: in $CH_3CH(OH)CH_3$ the OH hangs off the middle carbon.

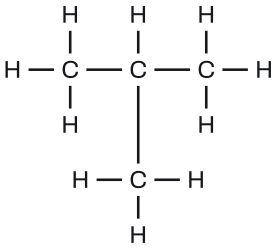
Products of later reactions are named the same way. A halogen atom is a prefix, with a number when needed: CH_3Cl chloromethane, C_2H_5Cl chloroethane, $CH_3CH_2CH_2Cl$ 1-chloropropane, $CH_3CHClCH_3$ 2-chloropropane, $BrCH_2CH_2Br$ 1,2-dibromoethane. A salt of a carboxylic acid takes the metal's name and the ending -oate: CH_3COONa is sodium ethanoate and $(CH_3COO)_2Ca$ is calcium ethanoate.

Structural isomers (Extended only)

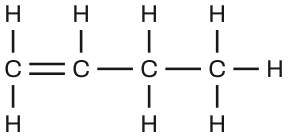
Structural isomers are compounds with the **same molecular formula** but **different structural formulae**. Four carbon atoms can be joined in a straight chain or with a branch, and a double bond or an $-OH$ can sit in different places.



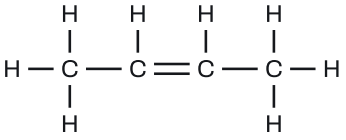
butane
$CH_3CH_2CH_2CH_3$



methylpropane
$CH_3CH(CH_3)CH_3$



but-1-ene
$CH_2{=}CHCH_2CH_3$

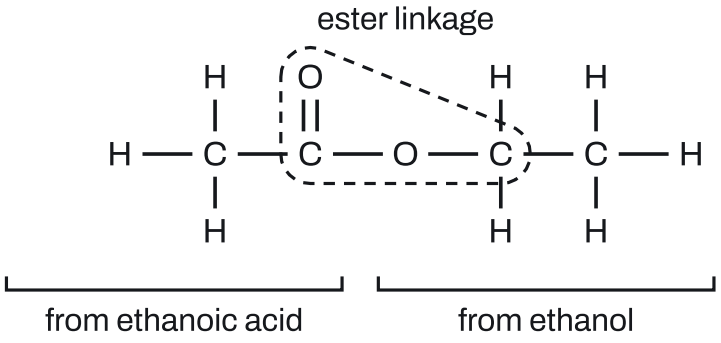


but-2-ene
$CH_3CH{=}CHCH_3$

The same molecule drawn with a bent chain, turned round or flipped over is **not** a new isomer: follow the bonds, not the shape on the page. $CH_3CH_2CH{=}CH_2$ is but-1-ene written backwards. Isomers can even be in different series: $C_4H_8O_2$ is butanoic acid (a carboxylic acid) but also three unbranched esters: propyl methanoate, ethyl ethanoate and methyl propanoate.

Esters (Extended only)

An **ester** forms when a carboxylic acid reacts with an alcohol (the reaction itself is in the carboxylic acids topic). The acid loses the $-OH$ of its COOH and the alcohol loses the H of its OH, and the two parts join through the **ester linkage**, $-COO-$.



ethyl ethanoate

$CH_3COOCH_2CH_3$

To **name** an ester, write the alcohol's part first as an "-yl" word, then the acid's part with "-oate":

- alcohol part: methanol → methyl, ethanol → ethyl, propan-1-ol → propyl, butan-1-ol → butyl;
- acid part: methanoic acid → methanoate, ethanoic → ethanoate, propanoic → propanoate, butanoic → butanoate.

So ethanol + ethanoic acid → **ethyl ethanoate**. In a structural formula like $\mathrm{CH_3COOCH_2CH_3}$, the carbons **before** COO (plus the C of COO) are the acid part, and the carbons **after** the O are the alcohol part. Reading from the other end, $\mathrm{CH_3CH_2OOCCH_3}$ is the same ester.

Trends in physical properties

Down a homologous series the molecules get bigger, so the forces between molecules get stronger. As the chain length increases:

- **boiling point** and **melting point** increase;
- **viscosity** increases (the liquid gets thicker and flows less easily);
- **volatility** decreases (the substance evaporates less easily).

The rise is gradual, so a missing value in a table lies **between** its neighbours.

Key facts and formulas

Nothing in this topic is given in the exam (the paper gives only the Periodic Table), so everything below is to learn.

Formula	Status
Alkanes $\mathrm{C_nH_{2n+2}}$ (ending -ane)	Learn it
Alkenes $\mathrm{C_nH_{2n}}$ (ending -ene; functional group C=C)	Learn it
Alcohols $\mathrm{C_nH_{2n+1}OH}$ (ending -ol; functional group $-\mathrm{OH}$)	Learn it

Formula	Status
Carboxylic acids $\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{COOH}$ (ending -oic acid; functional group $-\mathrm{COOH}$; n does not count the COOH carbon)	Learn it
Extended: acids and esters $\mathrm{C}_n\mathrm{H}_{2n}\mathrm{O}_2$; ester linkage $-\mathrm{COO}-$; name = alcohol part (-yl) + acid part (-oate)	Learn it
Consecutive members differ by $-\mathrm{CH}_2-$, so M_r differs by 14	Learn it
Stems: meth- 1, eth- 2, prop- 3, but- 4 carbon atoms	Learn it
Bonds: C forms 4, O forms 2, H forms 1	Learn it
Covalent bonds in an alkane $\mathrm{C}_n\mathrm{H}_{2n+2}$: $3n + 1$ (all single)	Learn it (or count them)
Hydrocarbon: a compound of carbon and hydrogen only	Learn it
Saturated: all C–C bonds single; unsaturated: at least one C=C	Learn it
Structural isomers: same molecular formula, different structural formulae	Learn it

How to do it

In the questions we have tagged for this topic (143 questions, 2021–2025, on all four papers), the types came up this often. 58 of the 143 questions mix types, so the counts add up to more than 143.

Question type	Questions
Identify the homologous series or type of compound	49
Name a compound, or write or draw its formula from its name	34
Define a homologous series and give its characteristics	32
Saturated and unsaturated	31
Structural isomers: define, spot, count, draw and name	29
Molecular formula from a displayed or structural formula	25
Use or state a general formula	24
Circle or identify a functional group	16
Esters: name, parent acid and alcohol, draw	12
Empirical formula from a molecular formula	9
Trends in physical properties	8
Define a hydrocarbon, or say why a compound is or is not one	8
Count covalent bonds or groups in a molecule	4

1. Identify the homologous series or type of compound (49 questions)

1. **From a name**, read the ending: -ane alkane, -ene alkene, -ol alcohol, -oic acid carboxylic acid, -oate ester.
2. **From a displayed or structural formula**, find the functional group: C=C alkene, $-\mathrm{OH}$ on a carbon with no C=O alcohol, $-\mathrm{COOH}$ carboxylic acid, $-\mathrm{COO}-$ between two carbon groups ester, only C–C and C–H single bonds alkane.
3. **From a molecular formula**, test it against the general formulae. Only C and H: $\mathrm{C}_n\mathrm{H}_{2n+2}$ alkane, $\mathrm{C}_n\mathrm{H}_{2n}$ alkene. One O and $\mathrm{C}_n\mathrm{H}_{2n+2}\mathrm{O}$: could be an alcohol. Two O and $\mathrm{C}_n\mathrm{H}_{2n}\mathrm{O}_2$: could be a carboxylic acid (or an ester).
4. **"Which are in the same series?"** Put each compound in its series first; ignore the number of carbons.

Variations you will meet:

- **"How many of these are alkanes?"** Check each formula: $\mathrm{C}_3\mathrm{H}_8$ fits $\mathrm{C}_n\mathrm{H}_{2n+2}$ ($2 \times 3 + 2 = 8$); $\mathrm{C}_4\mathrm{H}_8$ does not.
- **Behaviour clues:** decolourises aqueous bromine or forms an addition polymer → alkene; dissolves to give an acidic solution (pH below 7), or reacts with a carbonate or an alkali → carboxylic acid; burns but is otherwise unreactive, or is a hydrocarbon with only single bonds → alkane; made from ethene and steam → alcohol (ethanol); methane is the main gas in natural gas.
- **Letter questions** ("which of structures C, D, E, F..."): a structure may be used once, more than once or not at all. Write the series next to each structure before you answer.
- **Name the series of each part of a bigger molecule**, for example a molecule with C=C, $-\mathrm{OH}$ and $-\mathrm{COOH}$ belongs to alkene, alcohol and carboxylic acid types at once. Give the series name, not a compound name, when the question asks for the series.

2. Name a compound, or write or draw its formula from its name (34 questions)

1. Count the carbons in the chain (include the COOH carbon) and choose the stem.
2. Add the ending for the series and, on Extended, the position number.
3. **To draw a displayed formula**, draw the carbon chain, put in the functional group, then add H atoms until every C has 4 bonds, every O has 2 and every H has 1. Draw every bond, including the O–H.

Variations you will meet:

- **Core favourites**: the displayed formula of ethane, ethene, ethanol or ethanoic acid (the first diagram). These are usually 2 marks: one for the right skeleton and functional group, one for everything correct. Missing the O–H bond loses a mark.
- **"Draw the member of the same series with two carbon atoms"**: identify the series, then draw ethane, ethene, ethanol or ethanoic acid.
- **Multiple choice "which is correctly named"**: check the stem (carbons) and the ending. Traps: "methene" cannot exist (one carbon cannot have C=C); chloroethane is $\mathrm{C}_2\mathrm{H}_5\mathrm{Cl}$, chloroethene has a C=C; $(\mathrm{CH}_3\mathrm{COO})_2\mathrm{Ca}$ is calcium **eth**anoate.

- **Extended**: name or write unbranched compounds with up to four carbons, with position numbers (butan-2-ol is $\mathrm{CH_3CH_2CH(OH)CH_3}$); name products of later reactions, such as the two chloropropanes from propane and chlorine, 1-chloropropane $\mathrm{CH_3CH_2CH_2Cl}$ and 2-chloropropane $\mathrm{CH_3CHClCH_3}$, or a dibromo compound from an alkene.

3. Define a homologous series and give its characteristics (32 questions)

1. **Definition**: a family of similar compounds with **similar chemical properties** (1 mark) because they have the **same functional group** (1 mark). Give both halves: some mark schemes give a mark for each.
2. **"Give two characteristics"** (Extended, 2 marks): any two of same functional group; same general formula; differ by $-\mathrm{CH_2}-$ from one member to the next; trend (gradual change) in physical properties; similar chemical properties.
3. **Read the stem first.** If it already lists some characteristics, give **other** ones. For alkanes, which have no functional group, "same general formula" and "differ by $-\mathrm{CH_2}-$" are the safe pair.

Variations you will meet:

- **"Why do members have similar chemical properties?"** Because they have the same functional group. Not "they are hydrocarbons", not "same number of carbons", not "covalent bonds".
- **"Give two reasons, from their structural formulae, why A and B are in the same series"**: they fit the same general formula (for example $\mathrm{C_nH_{2n}}$) and have the same functional group (say which: the C=C).
- **"How does one member differ from the next?"** By a $-\mathrm{CH_2}-$ unit; in M_r, by 14.
- **"State the term"** for a family of similar compounds: homologous series. For a formula like $\mathrm{C_nH_{2n}O_2}$: a general formula.
- **Multiple-choice traps**: members do **not** have the same molecular formula, the same M_r, the same physical properties or the same volatility; they do not differ by $\mathrm{CH_3}$; they are compounds, not elements.

4. Saturated and unsaturated (31 questions)

1. **Circle the part that makes it unsaturated**: ring one C=C (both carbons and the double bond). Never a C=O.
2. **Explain why it is unsaturated**: "it has a carbon–carbon double bond" (or "a C=C bond"). "It has a double bond" is not enough.
3. **Explain why it is saturated**: "all its carbon–carbon bonds are single bonds".

Variations you will meet:

- **Pick the unsaturated hydrocarbon** from formulae or a table: the one that fits $\mathrm{C_nH_{2n}}$, or whose name ends in -ene. Say which reason you used.
- **Compounds with O** (acids, alcohols): judge only the C–C bonds. Ethanoic acid is saturated; ethene is unsaturated and ethanol (made from it) is saturated.
- **Which hydrocarbon decolourises aqueous bromine?** The unsaturated one (the test itself is in the alkenes topic).

- **Which molecule has only single covalent bonds?** An alkane such as propane. An acid or ester has C=O, an alkene has C=C.
- **Which bonds are present in an unsaturated carboxylic acid?** C=C (unsaturated), C=O and O–H (from COOH).

5. Structural isomers: define, spot, count, draw and name (29 questions)

All on the Extended papers.

1. **Definition** (1–2 marks): compounds with the **same molecular formula** but **different structural formulae**.
2. **To spot isomers**, write the molecular formula of each structure. Only those with the same formula can be isomers. Then check they really are different: the same chain drawn bent, reversed or turned over is the same compound.
3. **To draw isomers**, move a branch, the C=C or the functional group to a different carbon, then fill in the H atoms and check the formula is unchanged.

Variations you will meet:

- **Unbranched isomers of an alkene or alcohol**: but-1-ene / but-2-ene; propan-1-ol / propan-2-ol; butan-1-ol / butan-2-ol. A **branched** isomer of C_4H_8 is methylpropene, $CH_2{=}C(CH_3)CH_3$; of C_4H_{10}, methylpropane.
- **Counting**: "how many unbranched isomers of C_4H_8 decolourise bromine?" The C=C can start on carbon 1 or carbon 2, so 2. "How many products C_4H_9Cl from methylpropane?" Count the **different kinds** of carbon with H on them: the three end CH_3 carbons are all alike, and the middle carbon is different, so 2.
- **Substitution products**: propane gives two isomers of C_3H_7Cl (Cl on an end carbon or on the middle carbon); butane gives two of C_4H_9Cl. Draw two **different** ones, not one and its mirror image.
- **Acids and esters**: an acid and an ester with the same molecular formula are isomers ($C_3H_6O_2$ is propanoic acid, methyl ethanoate or ethyl methanoate). To count unbranched esters of a formula, split the carbons between the acid part and the alcohol part (each at least 1). For $C_4H_8O_2$: 1 + 3, 2 + 2, 3 + 1, three esters.
- **Not isomers**: butane and butene (different formulae); propene and but-2-ene; propan-1-ol and butan-1-ol (they differ by CH_2: same series, not isomers).

6. Molecular formula from a displayed or structural formula (25 questions)

1. Count every C, then every H (including the H in OH and COOH groups), then every O.
2. Write one symbol per element with its number, in the order C, H, then O: $C_5H_8O_3$. Don't write "5C + 8H + 3O" or leave groups in, like C_3H_7COOH; that is a structural formula.
3. Check with bonds: every C should have 4 bonds.

Variations you will meet:

- Paper 3 almost always opens an organic question with an unfamiliar plant compound or acid drawn out in full: "deduce the formula to show the number of carbon, hydrogen and oxygen atoms" (1 mark).

- On Paper 4 the compound is given as a structural formula: $CH_3CH_2CH_2COOH$ is $C_4H_8O_2$.
- A ring of six carbons drawn with alternate double bonds still counts as six C atoms; count only the H atoms actually drawn on it.
- A molecule may contain another element (Si, N, Cl): include it.
- **"Which name is given to this type of formula?"** $CH_3CH{=}CH_2$ is a structural formula; C_3H_6 is a molecular formula; C_nH_{2n} is a general formula.

7. Use or state a general formula (24 questions)

1. **State** the general formula (1 mark), with the subscripts right: $C_nH_{2n+1}OH$, where the "+1" belongs to the subscript.
2. **From a table of members**, check a formula in the table against each general formula and pick the one that fits every row.
3. **Use it**: put in n. The alkane with 7 carbons is C_7H_{16}; the alcohol with 5 carbons is $C_5H_{11}OH$, which as a **molecular** formula is $C_5H_{12}O$.

Variations you will meet:

- **Match the style the question asks for.** "Molecular formula" means combine the atoms ($C_5H_{12}O$). "Deduce the formula" of a member when the table writes the others as $C_6H_{13}OH$ means follow that style ($C_8H_{17}OH$).
- **Carboxylic acids**: the acid with 3 carbons has $n = 2$, C_2H_5COOH (propanoic acid).
- **Which set of formulae share a general formula?** For example C_2H_4, C_3H_6, C_4H_8 all fit C_nH_{2n}.
- **Which formula is the same for methanol, ethanol and propanol?** The general formula (their molecular, structural and empirical formulae all differ).
- **From properties**: a series that decolourises bromine is C_nH_{2n}; one that gives an acidic solution is $C_nH_{2n+1}COOH$.
- **Extended**: acids and esters as $C_nH_{2n}O_2$, and the value of n for a named ester (all its carbons).

8. Circle or identify a functional group (16 questions)

1. **Alcohol**: ring the $-O-H$ (the O and its H) on a carbon that has no C=O.
2. **Carboxylic acid**: ring the whole COOH: the carbon, the C=O oxygen, the other O and its H. Not just the O–H, and not the carbon next door.
3. **Alkene**: ring the C=C.
4. **Ester linkage** (Extended): ring the carbon of C=O, both oxygens and the carbon joined to the single-bonded O.

Variations you will meet:

- **Draw the COOH group** showing all atoms and bonds: a carbon with a double bond to one O and a single bond to an O–H.

- **Multiple choice "which functional groups does this molecule contain?"**: check each group separately; one molecule can have several.
- **"Explain why 1 mol reacts with 2 mol of an alkali"**: the molecule has two carboxylic acid groups.

9. Esters: name, parent acid and alcohol, draw (12 questions)

All on Paper 4.

1. **Name from a structure**: find the COO. The side with the C=O (counting that carbon) is the acid part; the side joined through the single O is the alcohol part. Name = alcohol part (-yl) + acid part (-oate).
2. **Name the acid and alcohol for a named ester**: "butyl ethanoate" came from butan-1-ol and ethanoic acid. Give the numbered name for alcohols with 3 or more carbons (propan-1-ol, butan-1-ol).
3. **Draw the displayed formula**: acid part, then $-\mathrm{C}(=\mathrm{O})-\mathrm{O}-$, then the alcohol part, with every atom and bond (the third and fifth diagrams).

Variations you will meet:

- **Any ester with three carbons**: methyl ethanoate or ethyl methanoate.
- **Count carbons**: add the acid's and the alcohol's carbons (propyl ethanoate: 2 + 3 = 5).
- **Molecular formula** of a named ester: count all atoms; it fits $\mathrm{C}_n\mathrm{H}_{2n}\mathrm{O}_2$.
- **An ester from a diol**: a molecule with two OH groups can form an ester at each end with two acid molecules.

10. Empirical formula from a molecular formula (9 questions)

All on the Extended papers (Papers 2 and 4); working it out from percentages is in the moles topic.

1. Write the molecular formula (count atoms if you are given a structure).
2. Divide every number by the largest number that goes into all of them: $\mathrm{C}_6\mathrm{H}_{10}\mathrm{O}_2 \rightarrow$ divide by 2 $\rightarrow \mathrm{C}_3\mathrm{H}_5\mathrm{O}$.
3. If nothing divides into all of them, the empirical formula is the molecular formula.

Variations you will meet: every alkene has the empirical formula CH_2, so but-2-ene and ethene share it. Ethanoic acid, $\mathrm{C}_2\mathrm{H}_4\mathrm{O}_2$, is $\mathrm{CH}_2\mathrm{O}$.

11. Trends in physical properties (8 questions)

1. **State the trend**: "the boiling point increases as the number of carbon atoms increases" (or "down the series").
2. **Predict a missing value**: give a value **between** the two neighbours in the table (not equal to either), for example the average of the two.
3. **Another property with a trend** (Extended): name it and give its direction, for example viscosity increases, or volatility decreases, as the chain gets longer.

12. Define a hydrocarbon, or say why a compound is or is not one (8 questions)

1. **Definition**: a **compound** containing **carbon and hydrogen only**. Both "compound" and "only" matter; "contains carbon and hydrogen" also fits ethanol.
2. **Why X is a hydrocarbon**: its molecules contain only carbon and hydrogen atoms.
3. **Why X is not**: it also contains another element, for example ethanol contains oxygen (say oxygen atoms, not oxygen molecules or hydroxide ions).

Variations you will meet: "explain why V is an alkane" needs two points: it is a hydrocarbon (C and H only) **and** it has only single bonds (it is saturated). A multiple-choice question may compare ethane and ethanol: both burn to give water, but only ethane is a hydrocarbon.

13. Count covalent bonds or groups in a molecule (4 questions)

1. Draw the displayed formula and count every line: each single line is one covalent bond.
2. Shortcut for an alkane $\mathrm{C}_n\mathrm{H}_{2n+2}$: $(n-1)$ C–C bonds plus $(2n+2)$ C–H bonds $= 3n+1$. Propane has 10, butane 13.
3. Ethanol: 1 C–C, 5 C–H, 1 C–O and 1 O–H, so 8.

Variation: "which has the most $-\mathrm{CH}_2-$ groups?" Write the structural formula and count CH_2 groups joined by single bonds on both sides: butan-1-ol $\mathrm{CH}_3\mathrm{CH}_2\mathrm{CH}_2\mathrm{CH}_2\mathrm{OH}$ has 3; butane has 2; the $\mathrm{CH}_2=$ end of but-1-ene does not count.

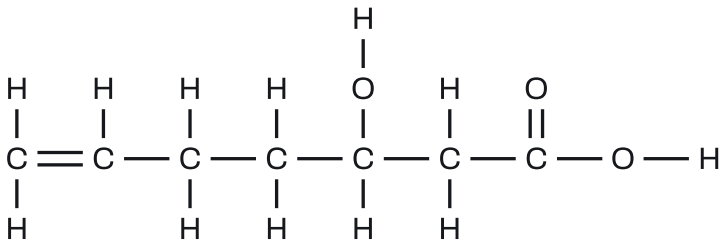
Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **B1** mark for a correct result on its own, with no method needed.

Example 1

Compound K is found in a fruit. Its displayed formula is shown.



(a) Deduce the molecular formula of compound K to show the number of carbon, hydrogen and oxygen atoms. **[1]**

(b) Compound K is unsaturated. State which bond shows this, and explain your answer. **[2]**

(c) Name the homologous series whose functional group is at the right-hand end of the molecule. **[1]**

(d) Explain why compound K is not a hydrocarbon. **[1]**

(e) Draw the displayed formula of the member of the series in (c) that has two carbon atoms. Show all of the atoms and all of the bonds. **[2]**

(a) Carbons: 7. Hydrogens: 2 + 1 + 2 + 2 + 1 (on the CH) + 1 (in the OH) + 2 + 1 (in the COOH) = 12. Oxygens: 1 (OH) + 2 (COOH) = 3. So $\mathrm{C_7H_{12}O_3}$. **B1**

(b) The C=C double bond at the left-hand end. **B1** Unsaturated means the molecule has a carbon–carbon bond that is not single; this is a carbon–carbon double bond. **B1** (The C=O at the other end does not count.)

(c) Carboxylic acids (the $-\mathrm{COOH}$ group). **B1**

(d) It contains oxygen as well as carbon and hydrogen; a hydrocarbon contains carbon and hydrogen only. **B1**

(e) Ethanoic acid: a $\mathrm{CH_3}$ carbon (three H, each drawn with its bond) joined to a carbon that has a double bond to one O and a single bond to an O, which is bonded to H (as in the first diagram). **B1** for the COOH group drawn correctly with all bonds, **B1** for the rest of the molecule.

Example 2

The table shows some members of a homologous series.

Name	Formula	Melting point / °C	Boiling point / °C
tetradecane	$\mathrm{C_{14}H_{30}}$	6	254
pentadecane	$\mathrm{C_{15}H_{32}}$	10	270
hexadecane	$\mathrm{C_{16}H_{34}}$	18	287
heptadecane		22	

Name	Formula	Melting point / °C	Boiling point / °C
octadecane	$\mathrm{C_{18}H_{38}}$	28	317

(a) Name the homologous series. **[1]**

(b) Deduce the general formula of this series. **[1]**

(c) A molecule of heptadecane has 17 carbon atoms. Deduce its molecular formula. **[1]**

(d) Predict the boiling point of heptadecane. **[1]**

(e) State the trend in the melting points as the number of carbon atoms increases. **[1]**

(f) These compounds are described as saturated. Explain what this means. **[1]**

(g) Define the term homologous series. **[2]**

(a) Alkanes (the names end in -ane). **B1**

(b) For tetradecane, $2 \times 14 + 2 = 30$, and the same works for every row, so $\mathrm{C}_n\mathrm{H}_{2n+2}$. **B1**

(c) $n = 17$, so $2(17) + 2 = 36$: $\mathrm{C_{17}H_{36}}$. **B1**

(d) Any value between 287 and 317 °C, for example 302 °C. **B1** A value equal to either neighbour would not be accepted.

(e) The melting point increases as the number of carbon atoms increases. **B1**

(f) All the carbon–carbon bonds in their molecules are single bonds. **B1**

(g) A family of similar compounds with similar chemical properties **B1** because they have the same functional group. **B1**

Example 3 (Extended)

Alcohol A has the structural formula $\mathrm{CH_3CH(OH)CH_2CH_3}$.

(a) Name alcohol A. **[1]**

(b) Alcohol B is an unbranched structural isomer of A that is also an alcohol. Name B and give its structural formula. **[2]**

(c) Explain why A and B are structural isomers. **[2]**

(d) Alcohol B reacts with butanoic acid to form ester E.

(i) Name ester E. **[1]**

(ii) Draw the displayed formula of E. Show all of the atoms and all of the bonds. **[2]**

(iii) Give the molecular formula and the empirical formula of E. **[2]**

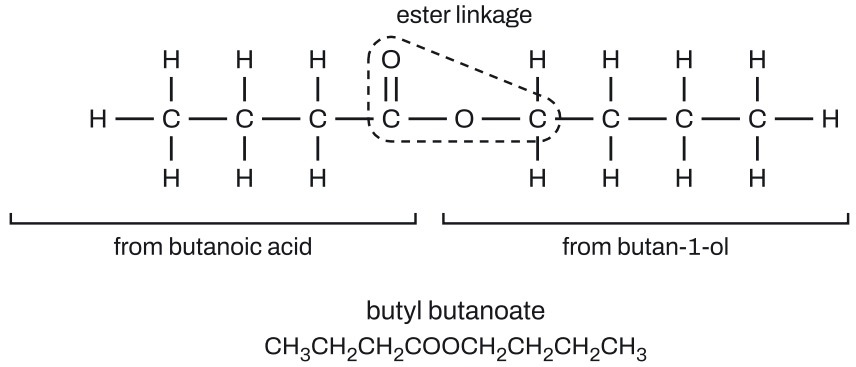
(a) Four carbons, OH on carbon 2: butan-2-ol. **B1**

(b) Butan-1-ol **B1**, $\mathrm{CH_3CH_2CH_2CH_2OH}$ **B1**.

(c) Both have the molecular formula $\mathrm{C_4H_{10}O}$ **B1**, but their structural formulae are different: the OH is on carbon 2 in A and on carbon 1 in B **B1**.

(d)(i) Alcohol part butyl (from butan-1-ol), acid part butanoate: butyl butanoate. **B1**

(ii) $\mathrm{CH_3CH_2CH_2COOCH_2CH_2CH_2CH_3}$, drawn out in full:



butyl butanoate
$\mathrm{CH_3CH_2CH_2COOCH_2CH_2CH_2CH_3}$

B1 for the ester linkage fully displayed (C=O and C–O–C), **B1** for the rest correct, with four carbons on each side.

(iii) Count: 8 C, 16 H, 2 O, so $\mathrm{C_8H_{16}O_2}$. **B1** Divide by 2: $\mathrm{C_4H_8O}$. **B1**

Example 4 (Extended, multiple choice)

(a) Which pair of compounds are structural isomers of each other? **[1]**

- A $\mathrm{CH_3CH_2CH_2CH_3}$ and $\mathrm{CH_3CH_2CH_2CH_2CH_3}$
- B $\mathrm{CH_3CH_2CH_2OH}$ and $\mathrm{CH_3CH(OH)CH_3}$
- C $\mathrm{CH_2{=}CHCH_2CH_3}$ and $\mathrm{CH_3CH_2CH{=}CH_2}$
- D $\mathrm{CH_3CH_2COOH}$ and $\mathrm{CH_3CH_2CH_2OH}$

(b) An alkene has a relative molecular mass of 84. What is its molecular formula? **[1]**

A $\mathrm{C_5H_{10}}$ B $\mathrm{C_6H_{12}}$ C $\mathrm{C_6H_{14}}$ D $\mathrm{C_7H_{14}}$

(c) How many covalent bonds are there in one molecule of pentane, $\mathrm{C_5H_{12}}$? **[1]**

A 15 B 16 C 17 D 18

(a) Write each molecular formula. A: $\mathrm{C_4H_{10}}$ and $\mathrm{C_5H_{12}}$, different. D: $\mathrm{C_3H_6O_2}$ and $\mathrm{C_3H_8O}$, different. B and C both match, but C is the **same** compound (but-1-ene) written from the other end. B is propan-1-ol and propan-2-ol, both $\mathrm{C_3H_8O}$. **Answer B.**

(b) An alkene is $\mathrm{C}_n\mathrm{H}_{2n}$, so $M_\mathrm{r} = 12n + 2n = 14n = 84$ and $n = 6$: $\mathrm{C}_6\mathrm{H}_{12}$. (C is an alkane, M_r 86.) **Answer B.**

(c) Pentane is an alkane, so the number of bonds is $3n + 1 = 3(5) + 1 = 16$ (4 C–C and 12 C–H). **Answer B.**

Common mistakes

- **Leaving the "+1" out of the subscript.** Examiners do not credit $\mathrm{C}_n\mathrm{H}_{2n+1}\mathrm{OH}$; the "2n+1" is one subscript. Write it clearly, and don't write "same molecular formula of $\mathrm{C}_n\mathrm{H}_{2n}$" when you mean the general formula.
- **Saying "double bond" without "carbon–carbon".** Unsaturated means a C=C. Answers such as "it has a double bond", "a carbon double bond" or "it is an alkene" miss the mark, and a C=O on its own does not make a molecule unsaturated.
- **Defining a hydrocarbon without "only".** "Contains carbon and hydrogen" is not enough; nor is "carbon and hydrogen bonds". Say a compound of carbon and hydrogen atoms only.
- **Writing a structural formula when a molecular formula is asked.** $\mathrm{C}_4\mathrm{H}_9\mathrm{COOH}$ or "5C + 10H + 2O" are not molecular formulae; write $\mathrm{C}_5\mathrm{H}_{10}\mathrm{O}_2$. Miscounting is common too: count the H in OH and COOH.
- **Incomplete displayed formulae.** Writing CH_3 or OH as a group, missing the O–H bond, or giving a carbon five bonds. Draw every bond and check each carbon has four. Don't add a molecular formula or an arrow to a displayed-formula answer.
- **Ringing the wrong atoms.** For an alcohol group, ring the O–H only, not the whole COOH or the CH next to it. For a carboxylic acid group, ring all four atoms of COOH, not just the OH or the C=O.
- **Naming the series when a compound is asked, or the other way round.** "Name compound C" wants a name like propanoic acid; "name the homologous series" wants a word like carboxylic acids. Spelling matters: "methenoic acid" suggests an alkene.
- **Ester names the wrong way round.** The alcohol part comes first: ethanol + propanoic acid gives ethyl propanoate, not propyl ethanoate. Alcohols with three or more carbons need their number (propan-1-ol, not propanol).
- **Drawing the same isomer twice.** A flipped or mirrored drawing of 1-chloropropane is still 1-chloropropane. Check that your two isomers have the functional group on different carbons, or a different chain.
- **Confusing isomers with members of a series.** Butane and butene are not isomers (different formulae); propan-1-ol and butan-1-ol are in the same series, not isomers.
- **Treating a homologous series as having identical properties.** Members have similar chemical properties but different physical properties that change gradually. They differ by a $-\mathrm{CH}_2-$ unit (not a "CH_2 molecule", not CH_3).

How to get the marks

- **"State" and "Name"** need the word or formula only, but it must be exact: the full name (butan-1-ol, ethyl ethanoate) and correct subscripts.

- **"Define"**: learn the definitions of homologous series, saturated, unsaturated, hydrocarbon and structural isomers word for word in meaning. Each has key words the mark scheme looks for: same functional group; carbon–carbon single bonds; carbon and hydrogen only; same molecular formula, different structural formulae.
- **"Deduce the molecular formula"**: one formula, one number per element, in the order C, H, O.
- **"Draw the displayed formula … show all of the atoms and all of the bonds"**: every bond as a line, including O–H and C=O. Two-mark drawings give one mark for the functional group or skeleton and one for the whole molecule, so a small slip costs only one mark.
- **"Circle"**: ring exactly the atoms of the group asked for, and only one group if the question says "one".
- **"Explain"** (why unsaturated, why a hydrocarbon, why isomers): give the reason in terms of the structure, for example "it has a carbon–carbon double bond".
- **"Give two characteristics"** and **"two reasons"**: two different points from the list; repeating one idea in other words scores once.
- **"Predict"** from a table: a value strictly between the neighbours. **"Suggest"**: apply the idea to an unfamiliar compound.
- **Use the information given.** If the question says "use Table 4.2", take the pattern (and the formula style) from the table.

Quick check

1. Name the homologous series of each compound: (a) $\mathrm{CH_3CH_2CH_2COOH}$ (b) $\mathrm{C_6H_{12}}$ (c) $\mathrm{CH_3CH(OH)CH_3}$ (d) $\mathrm{C_9H_{20}}$.
2. A compound has the structural formula $\mathrm{HOCH_2CH{=}CHCH{=}CHCOOH}$. Give its molecular formula and explain whether it is saturated or unsaturated.
3. Give the molecular formula of the alcohol with six carbon atoms, and calculate its relative molecular mass. (A_r: C = 12, H = 1, O = 16.)
4. (Extended) An ester is written from its alcohol end as $\mathrm{CH_3OOCCH_2CH_3}$. Name the ester and the alcohol and acid it is made from, and give its molecular and empirical formulae.
5. (Extended) How many structural isomers does $\mathrm{C_5H_{12}}$ have? Give their structural formulae.

Answers

1. (a) carboxylic acid (ends in COOH; it is butanoic acid); (b) alkene ($\mathrm{C}_n\mathrm{H}_{2n}$ with $n = 6$); (c) alcohol ($-\mathrm{OH}$; it is propan-2-ol); (d) alkane ($2 \times 9 + 2 = 20$).
2. C: 6; H: 2 + 1 + 1 + 1 + 1 + 1 (in OH) + 1 (in COOH) = 8; O: 3. So $\mathrm{C_6H_8O_3}$. It is **unsaturated** because it has carbon–carbon double bonds (two C=C).
3. $n = 6$: $\mathrm{C_6H_{13}OH}$, which is $\mathrm{C_6H_{14}O}$ as a molecular formula. $M_\mathrm{r} = 6(12) + 14(1) + 16 = 102$.
4. Read it the other way round: $\mathrm{CH_3CH_2COOCH_3}$. The C=O carbon and the two carbons before it come from propanoic acid; the $\mathrm{CH_3}$ joined through the single O comes from methanol. The ester is methyl propanoate. Atoms: 4 C, 8 H, 2 O, so $\mathrm{C_4H_8O_2}$; divide by 2 for the empirical formula $\mathrm{C_2H_4O}$.
5. Three: $\mathrm{CH_3CH_2CH_2CH_2CH_3}$ (pentane, a straight chain), $\mathrm{CH_3CH(CH_3)CH_2CH_3}$ (one branch) and $\mathrm{C(CH_3)_4}$ (a central carbon with four $\mathrm{CH_3}$ groups). All are $\mathrm{C_5H_{12}}$.

Past questions to try

- **0620/32/O/N/25 Q4**: the molecular formula of a plant compound, ringing the C=C, picking the unsaturated compound from a table, and drawing ethanol.
- **0620/22/O/N/25 Q34**: spotting which redrawn chains really are structural isomers.
- **0620/42/F/M/25 Q6**: why two alkenes are in the same series, the empirical formula, naming but-2-ene and drawing its isomer.
- **0620/41/M/J/25 Q5**: characteristics of a homologous series, the alcohol with five carbons, and naming the parts of an ester.