Exercise walk-through

Formulae, functional groups and terminology ▪ 11.1

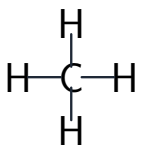
eXercise

You must be able to

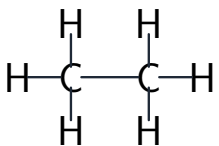
- use molecular, displayed, structural and general formulae
- describe a homologous series and its general formula
- recognise saturated/unsaturated and structural isomers

Method — Homologous series & isomers

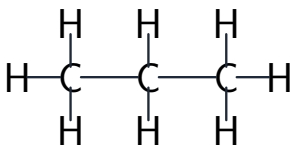
A homologous series: same functional group, differ by CH_2, general formula C_nH_{2n+2} for alkanes



methane
CH_4



ethane
C_2H_6



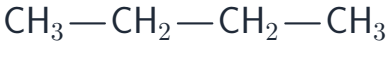
propane
C_3H_8

each step adds a CH_2 unit

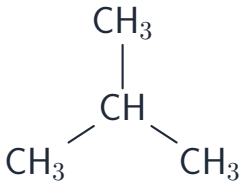
general formula C_nH_{2n+2}

Displayed formulae of methane, ethane, propane — each one CH_2 longer

Method — Homologous series & isomers



butane (straight chain)



2-methylpropane (branched)

both have the formula C_4H_{10}: same formula, different structure (structural isomers)

Butane (straight chain) and 2-methylpropane (branched)

Method — Naming, drawing and telling isomers apart

A **homologous series 同系列** is a family with the same **functional group 官能团**, the same general formula, and neighbours differing by CH_2. Along a series the boiling point rises as the molecules get longer, because the intermolecular forces between the larger molecules are stronger.

Series	**Functional group**	**General formula**	**First four**
alkanes	none (all single bonds)	C_nH_{2n+2}	methane, ethane, propane, butane
alkenes	$C=C$	C_nH_{2n}	ethene, propene, butene
alcohols	$-OH$	$C_nH_{2n+1}OH$	methanol, ethanol, propanol
carboxylic acids	$-COOH$	$C_nH_{2n+1}COOH$	methanoic, ethanoic, propanoic

Method — Naming, drawing and telling isomers apart

Three formulas, three jobs. The **molecular formula** counts the atoms (C_4H_{10}). The **structural formula** shows the order of the groups without drawing every bond ($CH_3CH_2CH_2CH_3$). The **displayed formula 结构式** draws every atom and every bond, so each carbon must show four bonds and each hydrogen one.

Structural isomers 结构异构体 have the same molecular formula but different structures, so they have different physical properties (for example different boiling points) while sharing the same chemical family.

Method — Naming, drawing and telling isomers apart

Worked example. Draw and name the two isomers of C_4H_{10}, and explain why they have different boiling points. Butane is a straight chain of four carbons; 2-methylpropane is a chain of three with a CH_3 branch on the middle carbon. Both must show every carbon with four bonds. Butane boils higher, because its unbranched molecules pack closer together, so the forces between them are stronger and more energy is needed to separate them.

Practice 2.1 ▪ 1 mark

State the general formula of the alkanes.

Solution 2.1

Worked steps

C_nH_{2n+2} B1.

Practice 2.2 ▪ 1 mark

Define a structural isomer.

Solution 2.2

Worked steps

compounds with the same molecular formula but different structural formulae B1.

Practice 2.3 ▪ 2 marks

State the general formula of the alkenes and give the molecular formula of the alkene with four carbon atoms.

Solution 2.3

Method: Naming, drawing and telling isomers apart

Worked steps

C_nH_{2n} B1; C_4H_8 B1.

Practice 2.4 ▪ 2 marks

State two features shared by all members of a homologous series.

Solution 2.4

Worked steps

Any two of: the same functional group; the same general formula; neighbouring members differ by CH_2; similar chemical properties; a gradual change in physical properties B2.

Practice 2.5 ▪ 2 marks

Explain why the boiling points rise as you go along a homologous series.

Solution 2.5

Method: Naming, drawing and telling isomers apart

Worked steps

The molecules get longer as the series is climbed B1, so the intermolecular forces between them are stronger and more energy is needed to separate them B1.

Exam-style 3.1 ▪ 1 mark

A saturated hydrocarbon contains:

A a C=C double bond

B only single C–C bonds

C an –OH group

D a –COOH group

Solution 3.1

A a C=C double bond

B only single C–C bonds ✓

C an –OH group

D a –COOH group

Worked steps

B. A saturated hydrocarbon has only single C–C bonds.

Exam-style 3.2 ▪ 1 mark

Members of a homologous series have similar chemical properties.
(a) State why they have similar chemical properties.
(b) State how consecutive members differ.

Solution 3.2

Method: Naming, drawing and telling isomers apart

Worked steps

(a) they have the same functional group B1.
(b) by a CH_2 unit each step B1.

Exam-style 3.3 ▪ 3 marks

Draw the two structural isomers of C_4H_{10} and name each.

Solution 3.3

Method: Naming, drawing and telling isomers apart

Worked steps

(a) The alkanes B1; C_nH_{2n+2} B1.
(b) A chain of five carbon atoms, each single-bonded B1, with every carbon showing four bonds and every hydrogen one, giving 12 hydrogens in total B1.
(c) A correct branched structure, for example 2-methylbutane: a four-carbon chain with a CH_3 group on the second carbon B1, drawn with all bonds shown B1; it is a structural isomer because it has the same molecular formula, C_5H_{12}, but the atoms are joined in a different order B1.
(d) The straight-chain molecules pack more closely together, so the intermolecular

Solution 3.3

forces between them are stronger **B1**; more energy is needed to separate them, so its boiling point is higher **B1**.
(e) The alkenes **B1**; an alkene contains a carbon-carbon double bond **B1**, and bromine adds across that double bond, so the orange bromine water is decolourised, which an alkane would not do **B1**.

Exam-style 3.3 ▪ 2 marks

A hydrocarbon X has the molecular formula C_5H_{12}.
(a) Identify the homologous series X belongs to, and give its general formula.
(b) Draw the displayed formula of the straight-chain isomer of X.
(c) Draw the displayed formula of one branched isomer of X, and explain why it is described as a structural isomer of your answer to (b).
(d) The straight-chain isomer boils at 36 °C and the branched one at 28 °C. Explain this difference.
(e) A different compound, Y, has the molecular formula C_5H_{10} and decolourises bromine water. Identify the homologous series of Y and explain how the test shows this.

Solution 3.3

Method: Naming, drawing and telling isomers apart

Worked steps

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Solution 3.3

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