Cambridge (CIE) IGCSE Chemistry

Your notes

Formulae, Functional Groups & Terminology

Contents

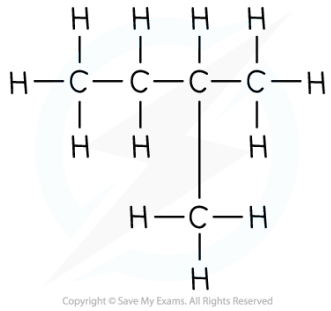
Your notes

Displayed formulae

- Organic Chemistry is the scientific study of the structure, properties, and reactions of organic compounds.
- Organic compounds are those which contain carbon
- For conventional reasons metal carbonates, carbon dioxide and carbon monoxide are **not** included in organic compounds
- Many of the structures you will be drawing are hydrocarbons
- A **hydrocarbon** is a compound that contains **only** hydrogen and carbon atoms
- Organic compounds can be represented in a number of ways:
  - Displayed Formulae
  - General Formulae
  - Structural Formulae

The **displayed formula** shows the spatial arrangement of all the atoms and bonds in a molecule

- For example:

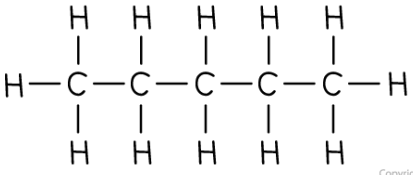


- This displayed formula tells us several things about the compound
  - It has 5 carbon atoms
  - It has 12 hydrogen atoms
  - It has only single bonds

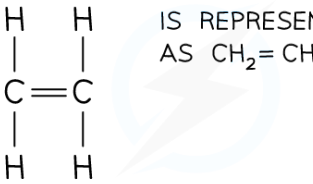
Structural formulae

Extended tier only

- In structural formulae, enough information is shown to make the structure clear, but most of the actual covalent bonds are omitted
- Only important bonds are always shown, such as double and triple bonds
- Identical groups can be bracketed together
- Side groups are also shown using brackets
- Straight chain alkanes are shown as follows:



IS REPRESENTED AS $CH_3CH_2CH_2CH_2CH_3$
OR $CH_3(CH_2)_3CH_3$



IS REPRESENTED AS $CH_2=CH_2$

Structural isomers

- Structural isomers are compounds that have the **same molecular** formula but **different structural** formulae
- The **molecular formula** is the **actual number** of atoms of each element in a compound
- Compounds with the same molecular formula can have different structural formulae due to the different arrangement of their atoms in space
- Two examples of structural isomers are shown below

Table showing structural isomerism in C_4H_{10}

Your notes

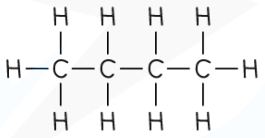
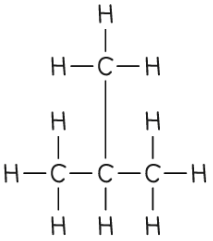
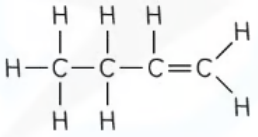
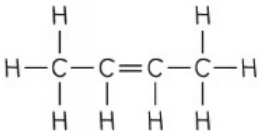
Molecular formula	C_4H_{10}	C_4H_{10}
Structural formula	$CH_3CH_2CH_2CH_3$	$CH_3CH(CH_3)CH_3$
Displayed formula		

Table showing structural isomerism in C_4H_8

Molecular formula	C_4H_8	C_4H_8
Structural formula	$CH_3CH_2CH=CH_2$	$CH_3CH=CHCH_3$
Displayed formula		

Examiner Tips and Tricks

Remember: Only double and triple bonds are shown in structural formulae.

Your notes

Your notes

Homologous series

- A homologous series is a family of organic compounds that have similar features and chemical properties due to them having the same **functional group**
- The functional group is a group of atoms which are bonded in a specific arrangement that is responsible for the characteristic reactions of each member of a homologous series

Table of compounds & their functional groups

Family	Functional Group	Name ends in...
Alkane	C-C	-ane
Alkene	C=C	-ene
Alcohol	-OH	-ol
Carboxylic acid	-COOH	-anoic acid
Ester	-COO-	-yl-anoate

Examiner Tips and Tricks

Make sure you can identify the functional group for each homologous series.

General formulae

- The **general formula** tells you the composition of any member of a whole homologous series of organic compound
- For example:
  - All of the alkanes have the general formula C_nH_{2n+2}, where n represents the number of carbon atoms
  - This tells you that however many carbon atoms there are in the alkane, doubling this number and adding two will give you the number of hydrogen atoms present in the alkane
- General formulae can be used to work out the formula of a compound from different homologous series if the number of carbon atoms present is known

General formula of common homologous series

Homologous Series	General Formula
Alkane	C_nH_{2n+2}
Alkene	C_nH_{2n}
Alcohol	$C_nH_{2n+1}OH$
Carboxylic acid	$C_nH_{2n+1}COOH$

Worked Example

Questions

1. What is the formula of an alcohol that contains 5 carbon atoms?
2. What is the formula of an alkene that contains 10 carbon atoms?

Answers:

1. The formula of an alcohol containing 5 carbon atoms is:

- Number of carbons = 5
- Number of hydrogen atoms (excluding in the functional group) = 2 x 5 + 1 = 11
- Formula = $C_5H_{11}OH$

2. The formula of an alkene that contains 10 carbon atoms is:

- Number of carbons = 10
- Number of hydrogen atoms = 2 x 10 = 20
- Formula = $C_{10}H_{20}$

General characteristic of homologous series

Extended tier only

- All members of a homologous series have:
  - The **same general formula**
  - **Same functional group**
  - **Similar chemical properties**
  - **Gradation** in their physical properties, such as melting and boiling point
  - The difference in the molecular formula between one member and the next is CH_2

Your notes

- These characteristics are shown below for ethanol and propanol, which belong to homologous series, alcohols

Your notes

Table of characteristics of ethanol and propanol

	Ethanol	Propanol
Molecular formula	CH_3CH_2OH	$CH_3CH_2CH_2OH$
General formula	$C_nH_{2n+1}OH$	$C_nH_{2n+1}OH$
Functional group	-OH	-OH
Boiling point (°C)	78	97

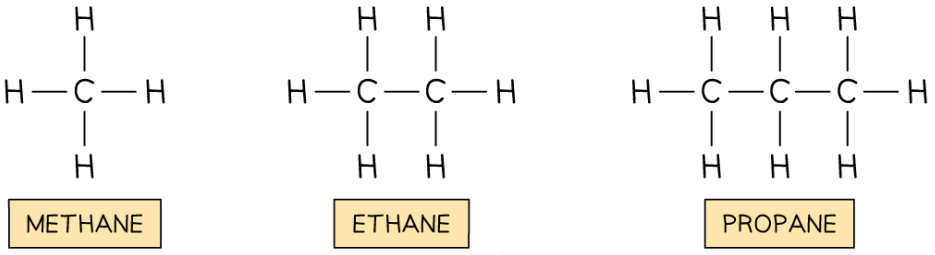
Examiner Tips and Tricks

Make sure you learn the general formula for each homologous series.

Your notes

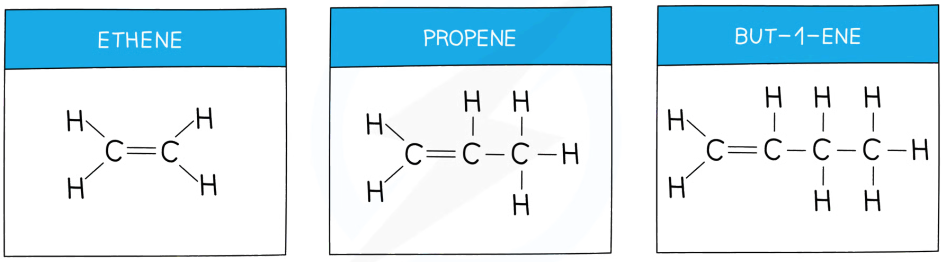
Saturated & unsaturated Compounds

- **Saturated compounds** have molecules in which all carbon-carbon bonds are **single bonds**
- Examples of compounds that are saturated are **alkanes**
- Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2}



Alkanes contain only carbon-carbon single bonds so are saturated

- **Unsaturated compounds** consist of molecules in which one or more carbon-carbon bonds are **not** single bonds
- They contain carbon-carbon **double bonds** (C=C)
- Examples of compounds that are unsaturated are alkenes.
- **Alkenes** are unsaturated hydrocarbons with the general formula is C_nH_{2n}
- The presence of the double bond, C=C, means they can **make more bonds** with other atoms by opening up the C=C bond and allowing incoming atoms to form another single bond with each carbon atom of the functional group
- Each of these carbon atoms now forms 4 single bonds instead of 1 double and 2 single bonds



Alkenes contain one carbon-carbon double bond so are unsaturated

Examiner Tips and Tricks

Remember: **S**aturated compounds have **S**ingle bonds only. **U**nsaturated compounds have do**U**ble bonds

Your notes

Your notes

Naming organic compounds

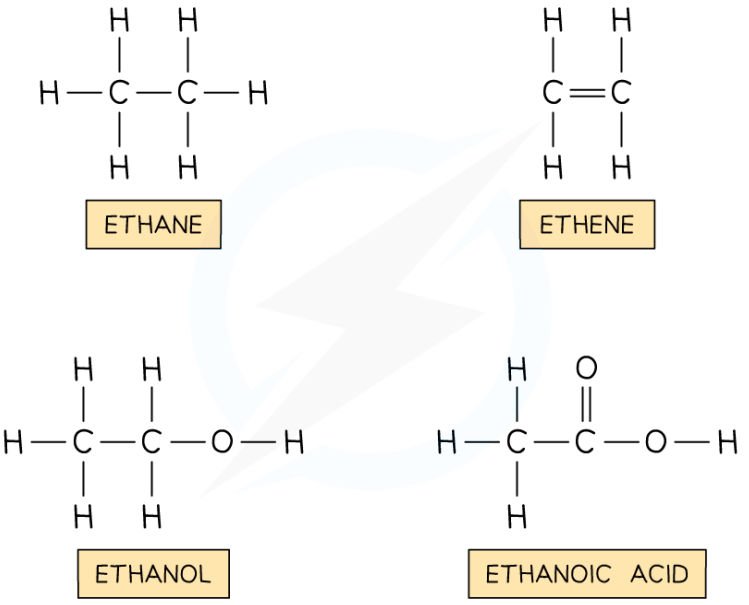
- The names of organic compounds have two main parts:
  - the stem (sometimes called the prefix)
  - end part (or suffix)
- The stem indicates the number of carbon atoms present in the longest continuous chain of the compound

Number of carbon atoms in the longest chain	Part of the chemical's name
1	meth
2	eth
3	prop
4	but
5	pent
6	hex

- The end part of the name tells you what **functional group** is in the compound

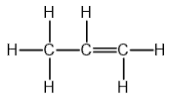
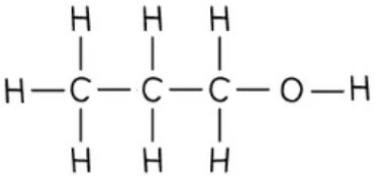
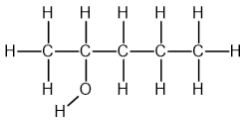
End part of the name	Functional group	Organic family
ane	none (contains only C-C bonds)	Alkane
ene	C=C bond	Alkene
anol	-OH	Alcohol
anoic acid	-COOH	Carboxylic acid
amine	$-NH_2$	Amine
-yl -anoate	-COO-	Ester

Your notes



Worked Example

Name the following organic compounds:

1	2	3
		

Answers:

1. Propene
    - The longest carbon chain is 3 carbons, so the name contains **prop**
    - The functional group is C=C, so the name contains **-ene**
2. Propanol
    1. The longest chain is 3 carbons, so the name is **prop**
    2. The functional group is OH, so the name contains **-anol**
3. Pentanol
    - The longest carbon chain is 5 carbons, so the name contains **pent**

- The functional group is OH, so the name contains **-anol**

Your notes

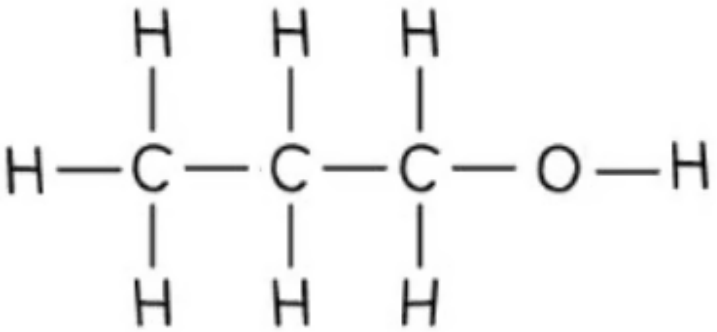
Examiner Tips and Tricks

Make sure you can draw and name the structures given above.

Further naming of organic compounds

Extended tier only

- When there is more than one carbon atom where a functional group can be located it is important to distinguish exactly **which carbon** the functional group is on
- Each carbon is numbered and these numbers are used to describe where the functional group is
- For example:
  - Propan-1-ol is an alcohol with an -OH functional group
  - The 1 in the name indicates that the -OH group is located on the first carbon atom
  - **Careful:** There are many times when the numbering should start from the right - this is to keep the numbers as low as possible in chemical names



In propan-1-ol the -OH group is located on the first carbon atom

Alkanes

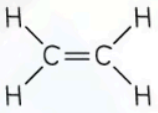
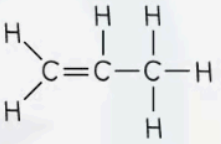
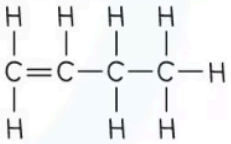
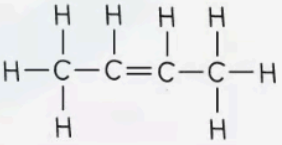
- As before, the number of carbon atoms gives the part of the compounds name
- Alkanes contain only **single carbon-carbon bonds**, **C-C**, which means that their name ends with **-ane**
  - Some compounds, like alcohols and carboxylic acids, have -an- in their name

- This indicates that those compounds contain only single carbon-carbon bonds, C–C

Your notes

Alkenes

- As before, the number of carbon atoms gives the part of the compounds name
- Alkenes contain at least one **double carbon-carbon bond**, **C=C**, which means that their name ends with **–ene**
  - The first alkene is ethene because you must have two carbons to be able to form a double carbon-carbon bond, C=C
- After propene, you must state the number of the first carbon that is part of the double carbon-carbon bond, C=C
  - e.g. but-1-ene has a double carbon-carbon bond, C=C, on the first carbon in the chain
  - But-2-ene has a double carbon-carbon bond, C=C, on the second carbon in the chain

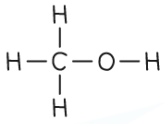
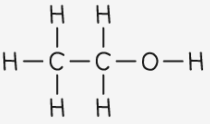
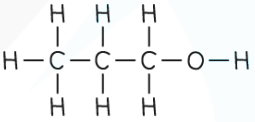
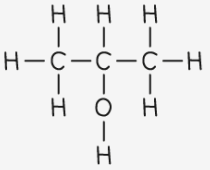
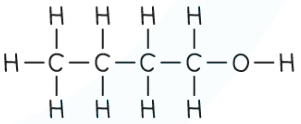
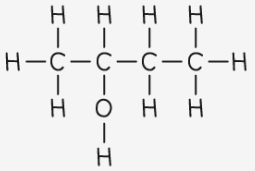
Alkene	Structural formula	Displayed formula
Ethene	$CH_2=CH_2$	
Propene	$CH_2=CHCH_3$	
But-1-ene	$CH_2=CHCH_2CH_3$	
But-2-ene	$CH_3CH=CHCH_3$	

Alcohols

- As before, the number of carbon atoms gives the part of the compounds name
- Alcohols contain an **alcohol / hydroxyl group**, **–O–H**, which means that their name ends with **–anol**

- After ethanol, you must state the number of the carbon that has the alcohol / hydroxyl group, –O–H, attached
  - e.g. propan-1–ol has the alcohol / hydroxyl group, –O–H, on the first carbon in the chain
    Propan-2–ol has the alcohol / hydroxyl group, –O–H, on the second carbon in the chain


Your notes

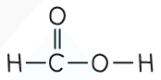
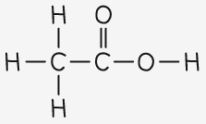
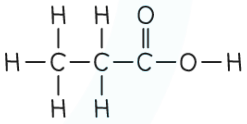
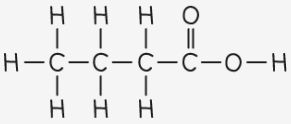
Alcohol	Structural formula	Displayed formula
Methanol	CH_3OH	
Ethanol	CH_3CH_2OH	
Propan–1–ol	$CH_3CH_2CH_2OH$	
Propan–2–ol	$CH_3CHOHCH_3$	
Butan–1–ol	$CH_3CH_2CH_2CH_2OH$	
Butan–2–ol	$CH_3CH_2CHOHCH_3$	

Carboxylic acids

- As before, the number of carbon atoms gives the part of the compounds name

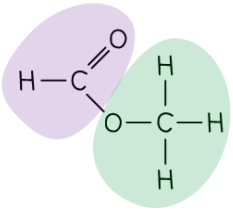
- Carboxylic acids contain a **carboxylic acid group**, **–COOH**, which means that their name ends with **–anoic acid**
- There is no need to number carboxylic acids because the carbon that is part of the carboxylic acid group is automatically the first carbon of the chain

Your notes

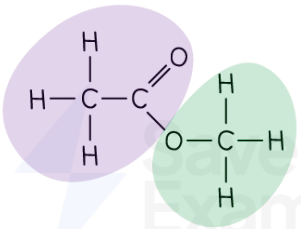
Carboxylic acid	Structural formula	Displayed formula
Methanoic acid	HCOOH	
Ethanoic acid	CH_3COOH	
Propanoic acid	CH_3CH_2COOH	
Butanoic acid	$CH_3CH_2CH_2COOH$	

Esters

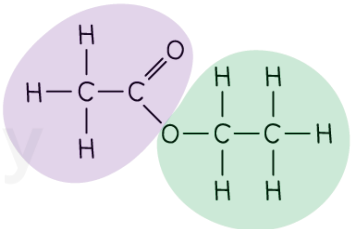
- Esters are one of the more challenging compounds to name
- Their name is based on the original alcohol and carboxylic acid that they were prepared from



METHYL METHANOATE

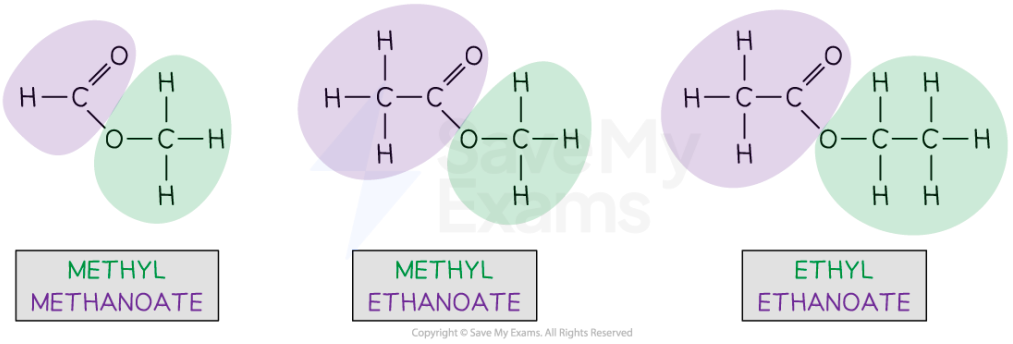


METHYL ETHANOATE



ETHYL ETHANOATE

- Ester names are confusing because the name is written backwards from the way the structure is drawn



- Methyl methanoate
  - The alcohol portion of the molecule contains the C–O single bond and is coloured green
    - There is one carbon, so this gives the methyl part of the name
  - The carboxylic acid portion contains the C=O double bond and is coloured purple
    - The is one carbon, so this gives the methanoate part of the name
- Methyl ethanoate
  - The alcohol portion of the molecule contains the C–O single bond and is coloured green
    - There is one carbon, so this gives the methyl part of the name
  - The carboxylic acid portion contains the C=O double bond and is coloured purple
    - The are two carbons, so this gives the ethanoate part of the name
- Ethyl ethanoate
  - The alcohol portion of the molecule contains the C–O single bond and is coloured green
    - There are two carbons, so this gives the ethyl part of the name
  - The carboxylic acid portion contains the C=O double bond and is coloured purple
    - The are two carbons, so this gives the ethanoate part of the name

Examiner Tips and Tricks

Extended tier students should be able to draw the structural and displayed formulae for all of the compounds written above.

Your notes