Mr Cole Science

Name: _____ Date: _____

AQA A-LEVEL CHEMISTRY

Chemical Formulae: Representing Organic Compounds

Learn Pack

Guided notes, worked examples and practice questions to be completed alongside the lesson.

WATCH THE LESSON

What is Organic Chemistry?

Lesson Objectives:

- Why organic chemists use different ways of representing compounds.
- The difference between molecular, empirical and general formulae.
- How to construct and interpret structural, displayed and skeletal

The term organic originally referred to living things.

Today, organic chemistry is defined as the study of carbon-based compounds.

Scientists once believed that organic compounds could only be produced by living organisms. Today, we know that this isn't true and carbon containing compounds are synthesised in laboratories and factories, which is why organic chemistry includes the following:

- Pharmaceuticals
- Fuels
- Plastics
- Synthetic Materials

Why is carbon so special?

Carbon has four electrons in its outermost shell. This allows it to form four covalent bonds meaning it can connect to multiple atoms at the same time, creating a huge variety of structures. Carbon also forms strong covalent bonds with other carbon atoms, as a result or this carbon can has the ability to form straight chains, branched chains and ring or cyclic structures. Carbon atoms can also form single, double and even triple bonds with both itself and other atoms.

The Representation Problem.

So, if carbon can form millions of different compounds, chemists need a reliable way of communicating exactly which compound they're talking about.

Different chemical formulae are needed because:

different chemical formulae emphasise different aspects or features of organic compounds and there isn't one single representation that is ideal for every purpose.

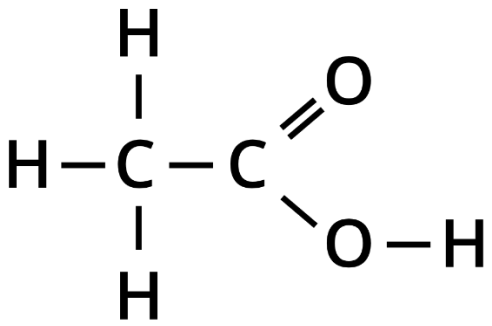
Molecular Formulae

Definition:

A molecular formula gives the actual number of atoms of each element in a molecule.

Worked Example:

Determine the molecular formula of ethanoic acid:



Element	Number of Atoms
Carbon	2
Hydrogen	4
Oxygen	2

Molecular Formula = $C_2H_4O_2$

Ethanol and Dimethyl ether:

Both compounds have the same molecular formula: C_2H_6O

Why is this a limitation of molecular formulae?

Because it's impossible to know which of the two compounds the molecular formula is referring to.

Summary:

Strengths of molecular formulae:

- Clearly show the exact number of atoms of each element.

Limitations of molecular formulae:

- Don't provide enough information to uniquely identify a substance.

Empirical Formulae

Definition:

An empirical formula gives the simplest whole number ratio of atoms of each element in a compound.

Worked Example:

Complete the table:

Molecular Formula	Empirical Formula
C_2H_6	CH_3
H_2O_2	HO
$C_2H_4O_2$	CH_2O
$C_6H_{12}O_6$	CH_2O

Summary:

Strengths of empirical formulae:

- Can be determined experimentally & used to work out the molecular formula of an unknown substance.

Limitations of empirical formulae:

- Don't give actual numbers of atoms present.
- Don't give any information about the structure.

General Formulae

Definition:

A general formula is an algebraic formula that describes every member of a homologous series.

Worked Example:

Complete the table below and answer the questions that follow:

Alkane	Molecular Formula
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}

What pattern can you identify?

The number of hydrogen atoms is always twice the number of carbon atoms plus two.

General Formula: C_nH_{2n+2}

What does 'n' represent?

The number of carbon atoms.

Summary:

Strengths of general formulae:

- Allows identification of patterns.
- Can be used to work out the molecular formula of any member of a homologous series.

Limitations of general formulae:

- Doesn't show how atoms are arranged.
- Doesn't provide details about specific molecules or compounds.

Structural Formulae

Definition:

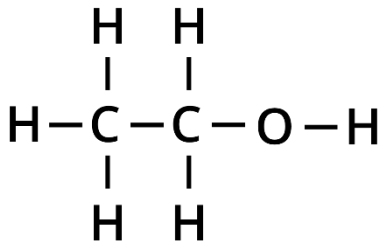
A structural formula shows how the atoms in a molecule are arranged by showing what's attached to each carbon atom.

Structural formulae can distinguish between compounds that have the same molecular formula but different structures, such as ethanol and di-methyl ether. Structural formulae are the standard representation used throughout most of organic chemistry and should always be used when writing symbol equations for organic reactions.

Worked Example:

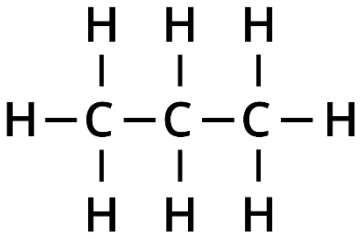
Write the structural formula for each of the compounds below:

Ethanol:



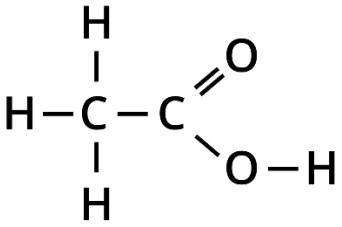
CH_3CH_2OH

Propane:



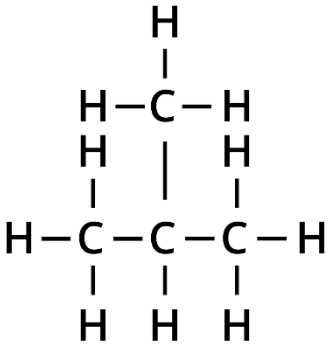
$CH_3CH_2CH_3$

Ethanoic Acid:



CH_3COOH

2-methyl propane:



$CH_3CH(CH_3)CH_3$

What do brackets represent in structural formulae?

They show that the group of atoms within them are attached to the previous carbon atom.

Summary:

Strengths of structural formulae:

- Show how atoms are arranged & therefore show functional groups.
- Distinguish between compounds with the same molecular formula.

Limitations of structural formulae:

- Don't explicitly show every bond.

Displayed Formulae

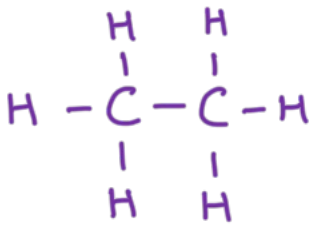
Definition:

A displayed formula is a more detailed structural formula that shows every atom and every bond.

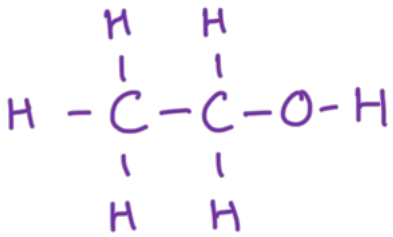
Worked Example:

Draw the displayed formula for each of the compounds below:

Ethane (CH_3CH_3):



Ethanol (CH_3CH_2OH):



Summary:

Strengths of displayed formulae:

- Shows how all atoms are arranged in space.

Limitations of displayed formulae:

- Not an efficient way of representing large or complex molecules.

Skeletal Formulae

Definition:

A skeletal formula is a shorthand representation of an organic molecule.

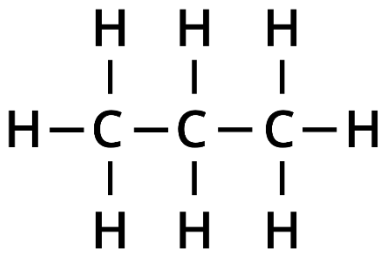
Rules of Skeletal Formulae:

1. Carbon atoms are not shown explicitly
2. Hydrogen atoms attached to carbon atoms are not shown.
3. Any atoms that are not part of the main hydrocarbon chain still need to be shown with the bonds connecting them to the chain.

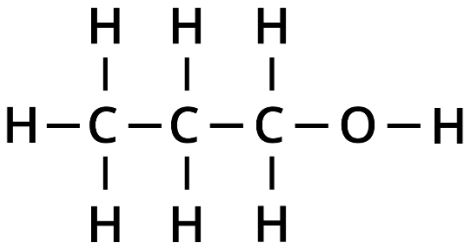
Worked Example:

Draw the skeletal formula for each of the compounds below:

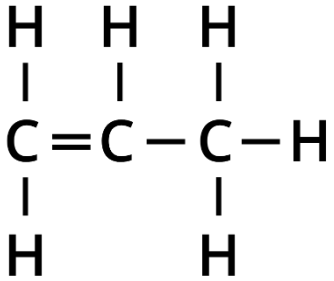
Propane:



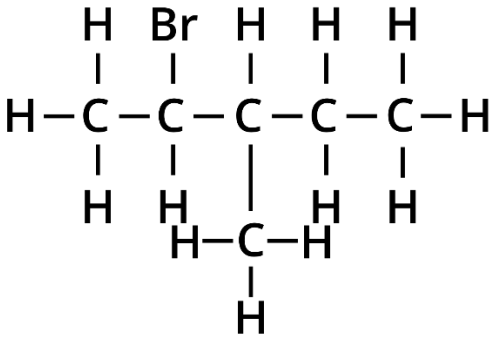
Propan-1-ol:



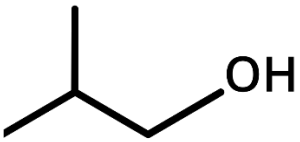
Propene:

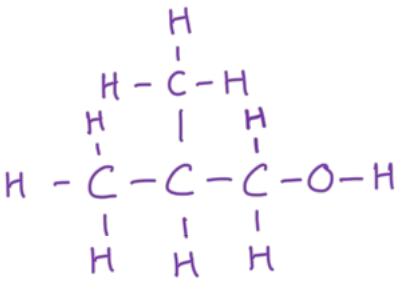


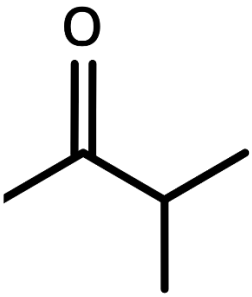
2-bromo-3-methyl pentane:

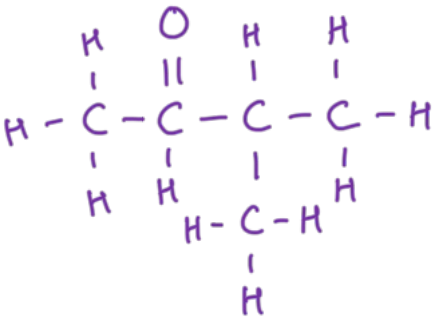


Draw the displayed formula for each of the compounds below:









Summary:

Strengths of skeletal formulae:

- Show how the atoms are arranged in an efficient way.

Limitations of skeletal formulae:

- Difficut to show the simplest of molecules containing only one carbon atom.

Practise Questions – Fact Recall

1. What is a molecular formula?

   The actual number of atoms of each element in a molecule.

2. How do you work out the empirical formula of a compound from the molecular formula?

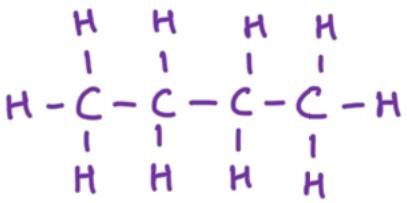
   Divide the number of atoms of each element by the highest common denominator.

3. What is a displayed formula?

   Detailed structural formula that shows every atom and every bond.

Practise Questions – Application

1. Write down the empirical formula of the following compounds:
   a) C_3H_6 — CH_2
   b) $C_{10}H_{12}Br_2$ — C_5H_6Br
   c) $C_9H_{17}Cl_3$ — $C_9H_{17}Cl_3$
2. Write or draw the following chemical formulae for butane, an alkane with 4 carbon atoms:
   a) Molecular formula C_4H_{10}
   b) Structural formula $CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$
   c) Displayed formula



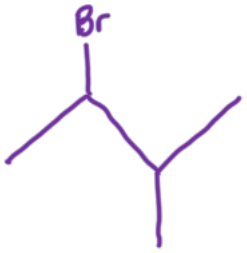
   d) Skeletal formula

3. Draw skeletal formulae for the following compounds:

$CH_3CH_2CH_2CH_2CH_3$

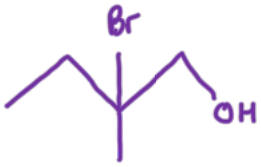
$CH_3CH_2CH(CH_3)CH_2CH_3$

$CH_3CHBrCH(CH_3)CH_3$



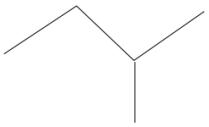
$CH_3CH(CH_3)CH_2CH_2OH$

$CH_3CH_2CBr(CH_3)CH_2OH$

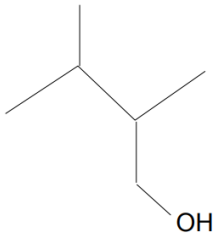


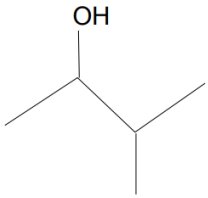
$CH_3CH(CH_3)CH_2CH_2Br$

4. Convert these skeletal formulae intro structural formulae:



$CH_3CH_2CH(CH_3)CH_3$





$CH_3CH(OH)CH(CH_3)CH_3$

$CH_3CH(CH_3)CH(CH_3)CH_2OH$

Follow the longest chain