Introduction

*Advanced Chemistry for You* is designed to help and support you during your Advanced Chemistry course. No matter which examination you are taking, this book will help you to make the transition to A Level.

The book is carefully laid out so that each new idea is introduced and developed on a single page or on two facing pages. Words have been kept to a minimum and are as straightforward as possible, with clear diagrams. Pages with a red triangle in the top corner are the more difficult pages generally needed for the full A Level qualification. Key words and facts are clearly printed in **bold** or placed in a highlight box. There is a summary of important facts at the end of each chapter, to help you with revision.

At the back of the book there are extra sections giving you valuable advice on study skills, practical work, revision and examination techniques, chemical data, as well as more help with mathematics.

Throughout the book there are *Chemistry at Work* pages. These show you how the chemical ideas that you learn are used in a wide range of interesting applications. There are also useful mapping grids that show how the book covers the different examination specifications, with full details of which pages you need to study, on the website at: [www.oxfordsecondary.co.uk/advancedforyou](http://www.oxfordsecondary.co.uk/advancedforyou)

At the end of each chapter there are a number of questions for you to practise your chemistry and so gain in confidence. They range from simple fill-in-a-missing word passage (useful for doing quick revision) to more difficult questions that will need more thought. At the end of each main topic you will find a section of Further Questions, mostly taken from actual A Level examination papers. The answers to all these Further Questions, as well as answers to all calculations, are given in a section at the back of the book. The answers to the rest of the end-of-chapter summary questions are provided on our website, along with a useful Glossary.

We hope that reading this book will make chemistry more interesting for you and easier to understand. Above all, we hope that it will help you to make good progress in your studies, and that you will enjoy using *Advanced Chemistry for You.*

Lawrie Ryan
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The great variety of life on Earth is built on the foundations of organic chemistry.
All organic compounds contain carbon atoms, although its oxides, carbonates and hydrogencarbonates are not classed as organic compounds.
The molecules that form the basis of all living things are based on carbon compounds.
Carbon atoms form the ‘backbone’ of these molecules – from the proteins that make up the muscles and enzymes in your body to the DNA that determines your characteristics.

### Functional groups

This section of the book looks at some groups of organic compounds. Each chapter deals with a class of compounds with similar structures. Particular groupings of atoms cause molecules to behave in certain ways.
These groupings are called **functional groups**. Look at the examples of functional groups below:

<table>
<thead>
<tr>
<th>Class of compounds</th>
<th>Functional group</th>
</tr>
</thead>
<tbody>
<tr>
<td>alcohols</td>
<td>R − O − H</td>
</tr>
<tr>
<td>aldehydes</td>
<td>R − C＝O</td>
</tr>
<tr>
<td>ketones</td>
<td>R − C＝O</td>
</tr>
<tr>
<td>carboxylic acids</td>
<td>R − C＝O − H</td>
</tr>
<tr>
<td>esters</td>
<td>R − C＝O − R</td>
</tr>
<tr>
<td>halogenoalkanes (haloalkanes)</td>
<td>R − X</td>
</tr>
<tr>
<td>amines</td>
<td>R − N＝H</td>
</tr>
<tr>
<td>amides</td>
<td>R − C＝NH₂</td>
</tr>
<tr>
<td>amino acids</td>
<td>R − C＝C＝O − H</td>
</tr>
<tr>
<td>nitriles</td>
<td>R − C＝N</td>
</tr>
</tbody>
</table>

where R is an **alkyl group**, or a hydrogen atom.
An alkyl group has the formula C\(_n\)H\(_{2n+1}\),
i.e. when \(n = 1\) we get CH\(_3\),
\(n = 2\) we get C\(_2\)H\(_5\),
\(n = 3\) we get C\(_3\)H\(_7\),
etc.

Notice that:
each carbon atom must have 4 covalent bonds;
each hydrogen 1 bond;
each oxygen 2 bonds; and
each nitrogen 3 bonds.

- Can you explain the number of bonds that each of the atoms above can form?
Homologous series

A ‘family’ of compounds that have a common functional group, with each successive member differing by $-\text{CH}_2-$, is called a homologous series. The simplest series of compounds is the alkanes. We will look in detail at these compounds in the next chapter. They are made from carbon atoms bonded to each other and to hydrogen atoms with single covalent bonds. Look at the displayed formulae of the first ten alkanes below:

Example 1

<table>
<thead>
<tr>
<th>Compound</th>
<th>Structural formula</th>
<th>Displayed formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>$\text{CH}_4$</td>
<td>$\text{H}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Ethane</td>
<td>$\text{C}_2\text{H}_6$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Propane</td>
<td>$\text{C}_3\text{H}_8$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Butane</td>
<td>$\text{C}<em>4\text{H}</em>{10}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Pentane</td>
<td>$\text{C}<em>5\text{H}</em>{12}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Hexane</td>
<td>$\text{C}<em>6\text{H}</em>{14}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Heptane</td>
<td>$\text{C}<em>7\text{H}</em>{16}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Octane</td>
<td>$\text{C}<em>8\text{H}</em>{18}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Nonane</td>
<td>$\text{C}<em>9\text{H}</em>{20}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
<tr>
<td>Decane</td>
<td>$\text{C}<em>{10}\text{H}</em>{22}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H}$</td>
</tr>
</tbody>
</table>

If you replace one of the H atoms with a functional group, you get a new homologous series. The functional group brings with it new physical properties and chemical reactions.

Example 2

<table>
<thead>
<tr>
<th>Compound</th>
<th>Structural formula</th>
<th>Displayed formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>$\text{CH}_3\text{OH}$</td>
<td>$\text{H}-\text{C}-\text{O}-\text{H}$</td>
</tr>
<tr>
<td>Ethanol</td>
<td>$\text{C}_2\text{H}_5\text{OH}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{O}-\text{H}$</td>
</tr>
<tr>
<td>Propanol</td>
<td>$\text{C}_3\text{H}_7\text{OH}$</td>
<td>$\text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H}$</td>
</tr>
</tbody>
</table>

You can find out how to name these alcohols on the next page.

This is the start of the homologous series of alcohols; $\text{CH}_3\text{OH}$, $\text{CH}_3\text{CH}_2\text{OH}$, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$, etc.

Organic formulae

Look at all the molecules drawn on this page: You can see each atom’s position in the molecule and the bonds between them. This way of showing a molecule is called its displayed formula. The structural formula gives us the atoms bonded to each carbon atom (see the examples of alcohols in Example 2 above). The skeletal formula is a simplified displayed formula. The only atoms shown are in the functional group(s).

Example 3

Butane ($M_r = 58$)
Empirical formula = $\text{C}_2\text{H}_5$
Molecular formula = $\text{C}_4\text{H}_{10}$
Structural formula = $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
Skeletal formula = \\[
  \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_3
\]
Naming organic compounds

There are millions of organic compounds. New ones are constantly being made in research labs all over the world. So chemists need a system of naming organic compounds that can be applied consistently. A name should tell us as much as possible about the molecules it describes. We can tell the number of carbon atoms from the alkane referred to in the name.

Look back to the alkanes on the previous page: Sometimes the alkane’s name is used in full. In other molecules, we use a shortened version:

<table>
<thead>
<tr>
<th>Number of carbons atoms</th>
<th>Abbreviation used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>meth-</td>
</tr>
<tr>
<td>2</td>
<td>eth-</td>
</tr>
<tr>
<td>3</td>
<td>prop-</td>
</tr>
<tr>
<td>4</td>
<td>but-</td>
</tr>
<tr>
<td>5</td>
<td>pent-</td>
</tr>
<tr>
<td>6</td>
<td>hex-</td>
</tr>
<tr>
<td>7</td>
<td>hept-</td>
</tr>
<tr>
<td>8</td>
<td>oct-</td>
</tr>
<tr>
<td>9</td>
<td>non-</td>
</tr>
<tr>
<td>10</td>
<td>dec-</td>
</tr>
</tbody>
</table>

Do you recall the table of functional groups on page 166? You need to recognise the way their compounds are named. Look at the table below:

<table>
<thead>
<tr>
<th>Class of compounds</th>
<th>Functional group</th>
<th>Recognised in name by ....</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>alcohols</td>
<td>—OH</td>
<td>-(an)ol</td>
<td>ethanol, butan-1-ol</td>
</tr>
<tr>
<td>aldehydes</td>
<td>—CHO</td>
<td>-(an)al</td>
<td>methanal, propanal</td>
</tr>
<tr>
<td>ketones</td>
<td>—CO—</td>
<td>-(an)one</td>
<td>butanone, hexan-2-one</td>
</tr>
<tr>
<td>carboxylic acids</td>
<td>—COOH</td>
<td>-(an)oic acid</td>
<td>octanoic acid, decanoic acid</td>
</tr>
<tr>
<td>esters</td>
<td>—COOR where R = alkyl group, e.g. CH₃ or C₂H₅</td>
<td>-(an)oate</td>
<td>methyl ethanoate, propyl hexanoate</td>
</tr>
<tr>
<td>halogenoalkanes</td>
<td>—CH₂X where X = halogen atom</td>
<td>fluoro-, chloro-, bromo-, iodo-</td>
<td>3-bromopentane, 1,2-dichloroethane</td>
</tr>
<tr>
<td>amines</td>
<td>—NH₂</td>
<td>-(yl)amine</td>
<td>ethylamine, butylamine</td>
</tr>
<tr>
<td>amides</td>
<td>—CONH₂</td>
<td>-(an)amide</td>
<td>pentanamide, heptanamide</td>
</tr>
<tr>
<td>amino acids</td>
<td>NH₂CR₂COOH where R = alkyl group or H atom</td>
<td>amino- -(an)oic acid</td>
<td>2-aminopropanoic acid, 2-aminobutanoic acid</td>
</tr>
<tr>
<td>nitrile</td>
<td>—CN</td>
<td>-nitrile</td>
<td>ethanenitrile, pentanenitrile</td>
</tr>
</tbody>
</table>

I.U.P.A.C. (the International Union of Pure and Applied Chemistry) devised the systematic way of naming organic molecules.

There are now well over 10 million compounds known on Earth.
Notice the shorthand used to represent the functional groups.

- Can you relate these to the displayed formulae in the table on page 166?
- Why do you think that some of the examples from the table have numbers in their names?

The system for naming compounds has to have some way of telling us the position of the functional group in the molecule. So we number the carbon atoms from the end nearest the functional group. Look at the example opposite:
- Can you see how both molecules are the same?
- Remember that the displayed formula is a 2D representation of a 3D molecule.
- How are four bonding pairs of electrons distributed around a central atom? (See page 62.)

Look at the 3D formula of chloroethane below, with bond angles of 109.5°:

Atoms can rotate around the single bonds (called sigma, σ, bonds – see page 190) from each carbon atom.

Therefore the displayed formulae shown below can all be used to represent the same molecule of chloroethane:

Here are the structural formulae of some examples from the previous table:

<table>
<thead>
<tr>
<th>Structural formula</th>
<th>Name</th>
<th>Structural formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃CH₂OH</td>
<td>butan-1-ol</td>
<td>Cl₂Cl₂</td>
<td>1,2-dichloroethane</td>
</tr>
<tr>
<td>CH₃CH₂C═O</td>
<td>propanal</td>
<td>CH₃CH₂CH₂NH₂</td>
<td>butylamine</td>
</tr>
<tr>
<td>CH₃CCH₂CH₃</td>
<td>hexan-2-one</td>
<td>CH₃CH₂CH₂C═ONH₂</td>
<td>pentanamide</td>
</tr>
<tr>
<td>CH₃CH₂CH₂CH₂CH₂C═O</td>
<td>octanoic acid</td>
<td>NH₂</td>
<td>2-aminopropanoic acid</td>
</tr>
<tr>
<td>CH₃C═O</td>
<td>methyl ethanoate</td>
<td>CH₃C≡N</td>
<td>ethanenitrile</td>
</tr>
</tbody>
</table>

- Not all the examples from the previous table are given here. Give the structural formulae of the rest.
Structural isomers

On the previous page we looked at some different ways of drawing the same molecule. However, given a molecular formula, we can sometimes draw different structures. Look at the examples below:

Molecular formula = C₃H₇Br

Example 5

<table>
<thead>
<tr>
<th>Br</th>
<th>H</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
1-bromopropane

<table>
<thead>
<tr>
<th>H</th>
<th>Br</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
2-bromopropane

The different displayed formulae above show molecules that can’t be superimposed on each other. They have different structures. The two different molecules are examples of structural isomers.

Isomers are molecules with the same molecular formula but different structural formulae.

In other words, isomers have the same number and type of atoms, but these are arranged differently within each molecule.

Example 6

Given the molecular formula C₃H₆Br₂, how many isomers exist?

<table>
<thead>
<tr>
<th>Br</th>
<th>Br</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
1,2-dibromopropane

<table>
<thead>
<tr>
<th>Br</th>
<th>H</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
1,3-dibromopropane

<table>
<thead>
<tr>
<th>Br</th>
<th>H</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>Br</td>
</tr>
</tbody>
</table>
1,1-dibromopropane

<table>
<thead>
<tr>
<th>H</th>
<th>Br</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>Br</td>
<td>H</td>
</tr>
</tbody>
</table>
2,2-dibromopropane

So there are four possible isomers. This is called position isomerism.

Notice that structures such as those shown below do not represent new isomers. They are repeats of the first isomer shown in the example above. You need to remember that groups can rotate around the C—C bonds when drawing isomers!

H H H  is the same as  Br H H  is the same as  Br H H
Br C C C H   H C C C H   H C C C Br
H Br H   H Br H   H C C H

All these are just different representations of the same isomer, i.e. 1,2-dibromopropane.
Now let’s consider the isomers with the formula C₃H₈O:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>H</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td></td>
<td>H</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>OH H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H C C C H</td>
<td>H H C C H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>propan-1-ol</td>
<td>propan-2-ol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This is another example of position isomerism. The two isomers are different molecules, but they are both alcohols. Therefore, they will undergo similar reactions, although there will be differences. For example, the rate of a particular reaction may well differ. Their physical properties will also be different. Look at the table opposite:

<table>
<thead>
<tr>
<th>Isomers</th>
<th>Boiling point / °C</th>
<th>Density / g cm⁻³ at 25 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>propan-1-ol</td>
<td>97.5</td>
<td>0.804</td>
</tr>
<tr>
<td>propan-2-ol</td>
<td>82.5</td>
<td>0.787</td>
</tr>
</tbody>
</table>

But can the atoms in C₃H₈O be arranged to make a molecule that is not an alcohol? Look at the isomer below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>H</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td></td>
<td>H</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>H C O C C H</td>
<td>H H C C H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>methoxyethane (an ether)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The properties of ethers are very different from those of the alcohols. This is an example of **functional group isomerism**.

- Will the ether above be able to form hydrogen bonds between its molecules? (See page 74.)
- What effect will this have on its boiling point compared with its isomers in the alcohol family?
- Why would you expect their chemical properties to be very different?

The last type of structural isomerism is sometimes called **chain isomerism**. Chain isomers differ in the way the carbon ‘backbones’ of the molecules are arranged. For example:

Remember that simply ‘bending’ or rotating the carbon chain in a displayed formula does not produce a different molecule.

You can see another example on the next page and find out about the differing physical properties of alkane chain isomers on page 177.
A sample of a hydrocarbon contained 14.4 g of carbon and 2.8 g of hydrogen. Its relative molecular mass is 86.0.

a) What is the compound's empirical formula?

b) What is its molecular formula?

c) Draw the structures of the different possible isomers. (Relative atomic masses: C = 12.0, H = 1.0)

a) Ratio of moles C : H

Number of moles of carbon = \(\frac{14.4}{12.0} = 1.2 \) moles

Number of moles of hydrogen = \(\frac{2.8}{1.0} = 2.8 \) moles

C : H

1.2 : 2.8

(to get the simplest whole-number ratio, divide both sides by 0.4)

C : H

3 : 7

Therefore the empirical formula is **C₃H₇**

b) The relative molecular mass of the compound is 86.0.

The relative molecular mass of C₃H₇ is \((12.0 \times 3) + (1.0 \times 7) = 43.0\)

\(\frac{86.0}{43.0} = 2\) so there are 2 units of C₃H₇ in this compound

i.e. its molecular formula is \((C₃H₇) \times 2 = C₆H₁₄\)

c) The structures of the possible isomers are:

- **Hexane**
  
  - or CH₃CH₂CH₂CH₂CH₂CH₃

- **2-Methylpentane**
  
  - or CH₃CH₂CH₂CH(CH₃)CH₃

- **3-Methylpentane**
  
  - or CH₃CH₂CH(CH₂)CH₂CH₃

- **Dimethylbutane**
  
  - or CH₃C(CH₃)₂CH₂CH₃

- **2,3-Dimethylbutane**
  
  - or CH₃CH(CH₃)CH(CH₃)CH₃
Stereoisomerism

As well as the structural isomers we saw on pages 170–172, we can also have stereoisomers. The molecules of stereoisomers have atoms that are each bonded to the same neighbouring atoms. However, the resulting molecules cannot be superimposed.

Everyday examples to help you imagine this could be a pair of gloves or shoes, or a left-hand and right-hand drive car. You can’t lay one shoe on top of the other, with both soles facing downwards, and get an identical match!

**E/Z isomerism**

One form of stereoisomerism is E/Z isomerism. Look at the example below:

Unlike a carbon–carbon single bond, the atoms cannot rotate around a carbon–carbon double bond. So the Br atoms in the first example are fixed on the same side of the molecule. When pairs of identical atoms, or groups of atoms, are on the same side of the double bond, we call it the Z-isomer. When the pairs are on opposite sides, it is called the E-isomer.

Sometimes you will see the prefixes cis- and trans- used instead of Z- and E respectively. This can only be used in compounds in which two of the substituent groups attached to each carbon atom of the C=C group are the same. So this does apply to the 1,2-dibromoethene example above.

No matter how you try, these two molecules cannot be placed directly on top of each other to give the same structure.

The best way to see this is to make models of the isomers yourself. Then try to superimpose them.

We can have E/Z stereoisomers whenever we have structures such as:

```
A   C   C   B   B   A
E   D   C   C   D   D
```

The carbon–carbon double bonds are shown, with the other atoms or groups of atoms bonded to the carbon atoms represented by letters A, B, D or E.

In the case of the first example above it is more difficult to identify the E- or Z- stereoisomer as no two groups around the C=C bond are the same. In such cases we apply a set of rules called the Cahn-Ingold-Prelog priority rules to assign E or Z when naming the stereoisomers (see page 187).
Optical isomerism

The other form of stereoisomerism is called optical isomerism. Naturally occurring amino acids (except glycine) are examples of optically active compounds (see page 257). However, any organic compounds containing an asymmetric carbon atom, i.e. bonded to 4 different atoms or groups of atoms, will be optically active – see below.

Optical isomers rotate the plane of polarised light.

Normal light is not polarised. It is made up from electromagnetic radiation, with electric and magnetic fields vibrating at right angles to each other in every possible direction. Light that has passed through polarised glass only vibrates in one direction. Look at the diagram opposite:

If a molecule contains a carbon atom bonded to four different groups then it exhibits optical isomerism. There are two ways to arrange the groups around the carbon atom so that they cannot be superimposed. The two optical isomers are mirror-images of each other. They are said to be asymmetric molecules. (Remember that stereoisomers are molecules with the same atoms and bonds but different arrangements in space.)

Look at the diagram below:

The two optical isomers are called enantiomers.

Make a model of two optical isomers. Try to place one on top of the other so that all the atoms correspond. Can you do it?

The carbon attached to four different atoms or groups is called the chiral centre.

The two molecules that are mirror images will rotate the plane of polarised light in different directions. One will rotate it left by the same amount that the other rotates it right. A mixture containing equal amounts of the two enantiomers is called a racemic mixture or racemate. The racemate has no effect on the plane of polarised light.

To distinguish the two enantiomers, the sign (+) or (−) is put in front of the name. (+) enantiomers rotate the plane of polarised light clockwise, whereas (−) ones rotate it anticlockwise. An example is (+)-alanine.

Enzymes in our bodies are sensitive to the structure of optical isomers. They will only work with one of the pair of enantiomers. All other properties and reactions of optical isomers will be the same.

All naturally occurring amino acids are optically active, except one.

● Why isn’t glycine optically active? Look at its structure on page 257.

You can also see stereoisomerism (E/Z and optical isomerism) in inorganic compounds. Page 144 shows stereoisomers of transition metal complexes.
Organic chemistry is the study of carbon-based molecules.

Organic compounds can contain one or more functional groups.

The functional groups determine a compound’s reactions.

We can represent an organic compound by its molecular formula, e.g. C\textsubscript{2}H\textsubscript{6}O, but its structural formula gives more information, e.g. CH\textsubscript{3}CH\textsubscript{2}OH.

Isomers are molecules with the same molecular formula, but different structural formulae.

There are three types of structural isomers:

i) position isomers,

ii) functional group isomers, and

iii) chain isomers.

There are two forms of stereoisomerism in which molecules with the same atoms and bonds are arranged differently in space – \textit{E/Z} isomerism and optical isomerism.

1. Name the following functional groups:
   a) R\textsubscript{2}C\equiv O
   b) R\textsubscript{2}C\equiv O
   c) R\textsubscript{2}C\equiv O
   d) R\textsubscript{2}O

2. Give the name, structural formula and displayed formula of the second member of the homologous series for each of these functional groups:
   For example, the alcohol will be:
   \[ \text{CH}_3\text{CH}_2\text{OH} \quad \text{and} \quad \text{CH}_3\text{CH}_2\text{OH} \]
   a) amine  c) aldehyde  e) amide
   b) nitrile  d) chloroalkane  f) carboxylic acid

3. A hydrocarbon has the empirical formula CH\textsubscript{2}. Its relative molecular mass is 42.0. What is its molecular formula?

4. Look at the formulae of the first ten alkanes shown on page 167:
   a) Work out a general formula for the alkanes shown.
   b) Give the molecular formula and structural formula of the next alkane in the homologous series.

5. Give the displayed formula of each of these compounds:
   a) propan-1-ol  f) octanenitrile
   b) butanal  g) ethyl butanoate
   c) pentan-2-one  h) 1,3-dichlorobutan-1-ol
   d) hexylamine  i) 2-aminopentanoic acid
   e) 2,3-dibromoheptane  j) 1,1,2-trifluoroethane

6. Name these molecules:
   a) \[ \text{CH}_3\text{CHCH}_3 \]
   b) \[ \text{CH}_3\text{CH}_2\text{C}\equiv \text{O} \]
   c) \[ \text{H} \equiv \text{C} \equiv \text{O} \]
   d) \[ \text{CH}_3\text{CH} \equiv \text{C} \equiv \text{CH}_3 \]
   (Hint: If we have more than one group in the name we write them in alphabetical order.)

7. Draw the structural isomers of:
   a) pentane
   b) 1-chlorobutane
   c) 1,1-dibromobutane.

8. A forensic scientist was asked to analyse a colourless liquid found at the scene of a crime. Her analysis showed that the compound contained 6.0 g of carbon, 1.5 g of hydrogen and 4.0 g of oxygen. Further analysis showed its relative molecular mass was 46.0.
   a) What is the empirical formula of the liquid?
   b) What is its molecular formula?
   c) Draw two possible isomers.
   d) Chemical tests showed that the compound was an alcohol.
   Name the colourless liquid.

9. a) Draw and name the \textit{E/Z} isomers of:
   (i) CHF\equiv CHBr
   (ii) CH\textsubscript{3}CH\equiv CHCH\textsubscript{3}
   b) (i) Explain which one of the following will display optical isomerism:
       \[ \text{CH}_3\text{OH}; \text{CH}_2\equiv \text{CHCl}; \text{CHBrClF} \]
       (ii) Draw the 3D formulae of the two enantiomers.