

Chapter 15

Organic Chemistry, Alkanes and Haloalkanes

NCEA Level 2 Chemistry material covered in this chapter includes material for Achievement Standard 90309 (Chemistry 2.5) 'Describe the structural formulae and reactions of compounds containing selected organic functional groups'. This chapter deals with:

- Recognising alkanes and haloalkanes.
- Naming or drawing structural formulae of straight or branched chain hydrocarbons (up to 8 carbon atoms) and haloalkanes (up to 8 carbon atoms).

Introduction

Organic chemistry is the study of the compounds of carbon. All compounds containing carbon (except carbon monoxide, CO, carbon dioxide, CO₂, and the carbonates, CO₃²⁻) are referred to as **organic compounds**. Organic compounds usually contain hydrogen and sometimes other atoms such as oxygen, nitrogen and chlorine.

Millions of different organic molecules are known, with thousands of new ones identified each year.

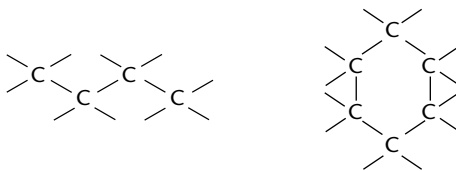
Organic molecules are found in:

- All living things – carbon atoms comprise about 20% (by mass) of all animals.
- **Fossil fuels** like coal, petroleum, oil and natural gas.
- Common products like plastics, adhesives, soaps, paper, cosmetics and medicine.

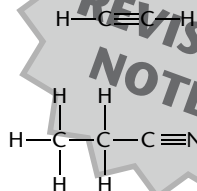
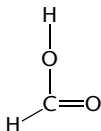
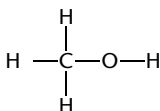
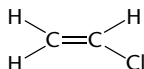
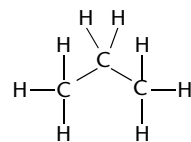


There are several reasons why there are so many organic molecules:

- Carbon atoms form covalent bonds with other carbon atoms, giving rise to long *chains* and *rings* of carbon atoms.

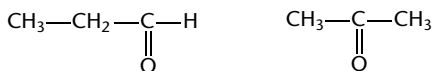


- Carbon atoms readily form single, double, and triple covalent bonds, both with carbon atoms and with different atoms.



SAMPLE
REVISION
NOTES

- The same atoms can join together differently to produce *isomers*.



The structure of organic compounds is based on a framework of carbon atoms, with hydrogen atoms usually completing the bonding requirements of the carbon atoms.

Hydrocarbons

The simplest organic compounds contain only hydrogen atoms and carbon atoms and are called **hydrocarbons**.

- Alkanes** contain only C—C single bonds. They are said to be **saturated**, as no more hydrogen atoms can be added to them.
- Alkenes** have one or more C=C double covalent bonds. They are said to be **unsaturated**, as hydrogen atoms can be added to them.
- Alkynes** have one or more C≡C triple covalent bonds and are *unsaturated*.

Functional groups

Atoms or groups of atoms which influence the chemical behaviour of a compound are called **functional groups**.

Double or triple bonds are examples of functional groups.

There are other functional groups, such as:

- Cl, —Br, —I found in **haloalkanes**.
- OH found in **alcohols**.
- $\begin{array}{c} \text{—C—OH} \\ \parallel \\ \text{O} \end{array}$ found in **carboxylic acids**.

- $\begin{array}{c} \text{—C—O—} \\ \parallel \\ \text{O} \end{array}$ found in **esters**.

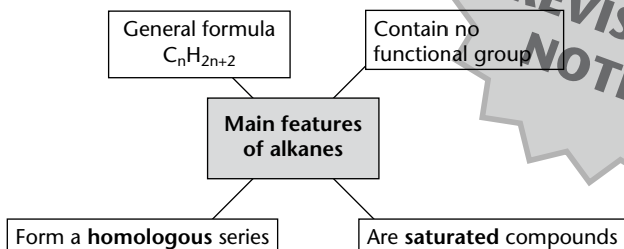
Homologous series

A **homologous series** is a family of organic compounds that can be represented by a general formula in which each successive member of the series differs by a —CH₂— unit.

Members of a homologous series have similar methods of preparation and have similar chemical properties.

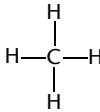
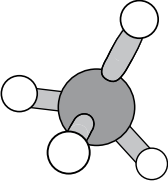
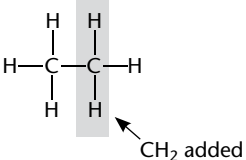
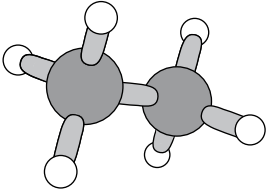
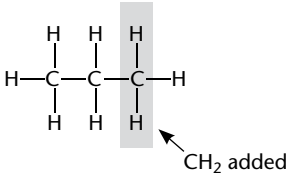
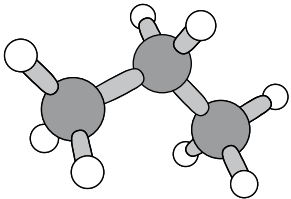
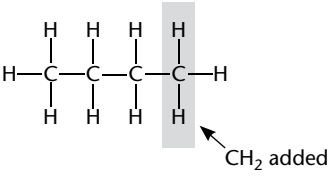
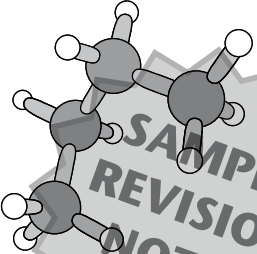
Alkanes

Alkanes are an example of a **homologous series**.



The alkane family builds by lengthening the carbon chain by one $\text{—CH}_2\text{—}$ group at a time:

- The first member of the alkane family, methane, contains only one carbon atom ($n = 1$). The number of hydrogen atoms in methane is $2n + 2 = 2 \times 1 + 2 = 4$, so the molecular formula is CH_4 .
- The second member of the alkane family contains two carbon atoms ($n = 2$), so the number of hydrogen atoms is $2 \times 2 + 2 = 6$. This alkane is called ethane, and has the molecular formula C_2H_6 .
- The third member of the family has three carbons ($n = 3$), so the number of hydrogen atoms is $2 \times 3 + 2 = 8$. This alkane is called propane, and has molecular formula C_3H_8 .

First four members of the alkane homologous series	
<p>Methane, CH_4</p>  	<p>Ethane, C_2H_6</p>  
<p>Propane, C_3H_8</p>  	<p>Butane, C_4H_{10}</p>  

**SAMPLE
REVISION
NOTES**

Naming Straight-Chain Alkanes

In a **straight-chain** alkane, all of the carbon atoms are joined one after the other in a single 'line'. Straight-chain alkanes are named by placing the appropriate prefix in front of the suffix *-ane*:

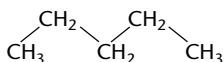
Number of carbon atoms in chain	Prefix	Alkane name
1	meth-	methane
2	eth-	ethane
3	prop-	propane
4	but-	butane
5	pent-	pentane
6	hex-	hexane
7	hept-	heptane
8	oct-	octane
9	non-	nonane
10	dec-	decane

Example A

Straight-chain alkanes

$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$ is *butane* because there are four carbons.

C_6H_{14} is *hexane* because there are six carbon atoms.



is *pentane* because there are five carbon atoms.

(Note that the pentane chain – and this is true for all straight-chain alkanes – is not 'straight' as such. The C atoms are aligned in a zigzag fashion due to the tetrahedral arrangement of bonds around the carbon atom; regardless of this, the shape is described as 'straight-chain'.)

SAMPLE
REVISION
NOTES

Molecular and Structural Formulae

A **molecular formula** gives information about the type and number of atoms present in a substance. Methane has the molecular formula CH_4 . Methane molecules contain one carbon and four hydrogen atoms.

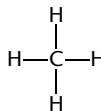
A **structural formula** shows how the atoms are joined together.

Example B

Structural formula of methane, CH_4

Methane has the structural formula shown alongside.

The structural formula shows that each hydrogen atom is attached to the carbon atom by a single covalent bond.

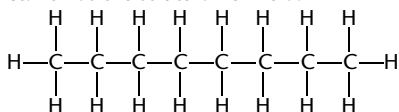


Usually, a **condensed structural formula** is used to represent organic compounds, especially for larger molecules.

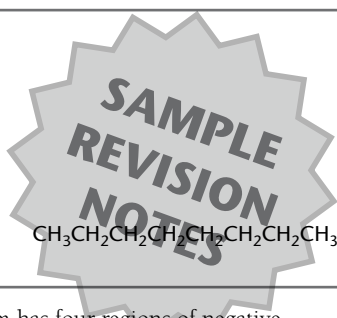
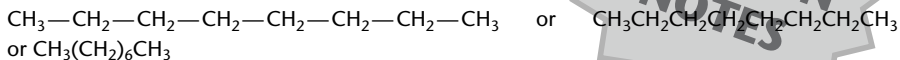
Large alkanes (especially) usually have all the $-\text{CH}_2$ groups 'collected together' and written in brackets with a number.

Example C**Octane**

Octane has the structural formula:

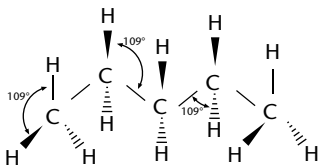


A condensed structural formula of octane would be:

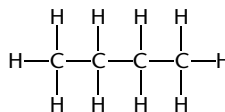


Alkanes have angles of 109° between the bonds – each C atom has four regions of negative charge, so the geometry is tetrahedral. With several atoms in the chain, a zigzag shape occurs.

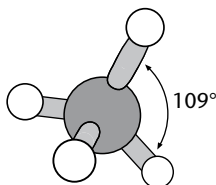
In Lewis structures and structural formulae, the molecules are often simplified to give planar views with angles of apparently 90° .

Example D**Bond angles in alkanes**

Butane, C_4H_{10} , has bond angles of 109° , giving a zigzag structure.



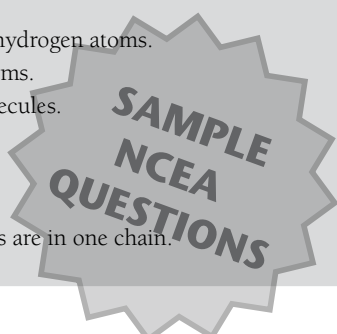
A simplified diagram shows butane as a planar structure.



Model of methane showing bond angle of 109° .

Activity 15A: Introduction to Alkanes

- Write down electron arrangements for carbon and hydrogen atoms.
 - Draw Lewis structures for carbon and hydrogen atoms.
 - Draw Lewis structures for methane and ethane molecules.
- Draw structural formulae for:
 - Ethane.
 - The alkane with three carbon atoms.
 - The alkane, C_6H_{14} , where the six carbon atoms are in one chain.
 - Give the condensed structural formulae for C_6H_{14} .



3. For the formula C_nH_{2n+2} , write molecular formulae of the alkanes where:

- a. $n = 2$ b. $n = 4$ c. $n = 10$ d. $n = 32$

4. Name the straight-chain compounds which have the following formulae:

- a. C_5H_{12} b. C_4H_{10} c. The alkane with seven carbon atoms.
d. CH_4 e. The alkane with eight carbon atoms.

5. a. Explain the meaning of the following terms:

- i. Homologous series. ii. Saturated hydrocarbon.

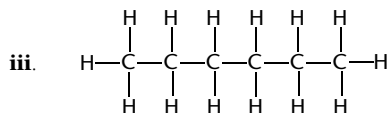
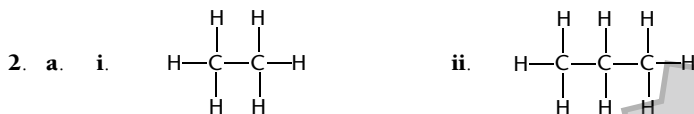
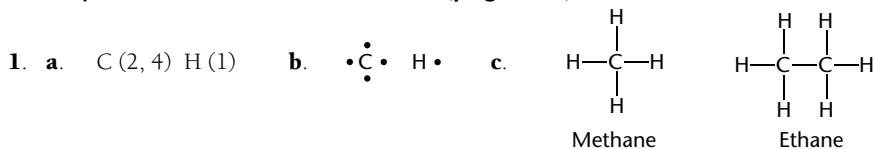
- b. Give an example for each of the terms in a.

SAMPLE
NCEA
QUESTIONS

Answers

(A), (M) or (E) next to an answer shows whether the answer was worth 'Achieved', 'Merit' or 'Excellence'. The assignment on these grades has been made according to the best judgment of the authors at the time of writing. Answers with no NCEA grade are from questions designed to help understanding; they are not NCEA-style questions.

Activity 15A: Introduction to Alkanes (page 131)



- b. $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$ or $CH_3(CH_2)_4CH_3$

3. a. C_2H_6 b. C_4H_{10} c. $C_{10}H_{22}$ d. $C_{32}H_{66}$

4. a. Pentane. b. Butane. c. Heptane. d. Methane. e. Octane. (A)

5. a. i. Family of compounds with the same functional group and where each new member contains an additional $-CH_2-$ group. (A)

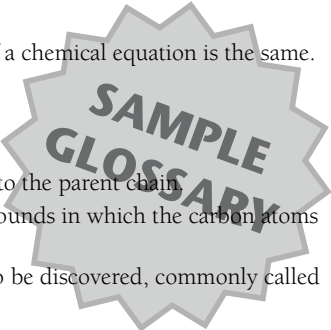
ii. A compound of hydrogen and carbon with only single bonds between atoms. (A)

b. The alkanes form a homologous series. The alkanes are saturated hydrocarbons. (A)

SAMPLE
NCEA
ANSWERS

Glossary/Index

- acetic acid (164):** a common name for ethanoic acid.
- acid-base titration (25):** an experimental procedure where a neutralisation reaction is used to determine the concentration of an acid or a base.
- acidified (244):** has had acid added, or occurring in acidic solution.
- addition (150):** reaction that involves breaking a double (or triple) bond between carbon atoms and forming a single (or double) bond in its place as well as forming two new single covalent bonds.
- addition polymerisation (154):** alkene monomers joining together to form a polymer.
- alcohols (128):** organic compounds that contain a hydroxyl, $-\text{OH}$, group.
- aliquots (28):** fixed volumes of liquid delivered by a pipette.
- alkaline (223):** solution containing more hydroxide ions than hydronium ions.
- alkanes (128):** hydrocarbons containing only single bonds.
- alkenes (128, 145):** hydrocarbons which contain a carbon-carbon double bond (ie $\text{C}=\text{C}$).
- alkyl groups (133):** side chain branches; named after the respective alkane (eg methane \longrightarrow methyl).
- alkynes (128):** hydrocarbons which contain a carbon-carbon triple bond (ie $\text{C}\equiv\text{C}$).
- allotrope (105):** different physical form of an element.
- alpha (symbol α) particles (72):** nuclei of helium atoms.
- alumina (256):** aluminium oxide.
- amphiprotic (224):** can either accept or donate protons.
- amphoteric (13):** metal oxide or hydroxide that can be acidic (react with bases) or basic (react with acids).
- analysis (51):** separation of compounds/mixtures into their constituents and/or properties of constituents.
- anhydrous (56, 64):** no water of crystallisation present.
- anions (3, 79, 253):** negatively charged ions.
- anode (253):** the electrode at which oxidation occurs.
- antifreeze (161):** substance used in car radiators to prevent water freezing; 1,2-ethanediol is an important component.
- aqueous (59):** dissolved in water.
- atomic number (symbol Z) (72):** the number of protons in the nucleus of an atom.
- Avogadro's number (40):** 6.02×10^{23} particles.
- balanced (45):** number of each type of atom on both sides of a chemical equation is the same.
- basic (223):** can neutralise acids.
- bauxite (256):** a red-brown ore containing aluminium oxide.
- bonding electrons (84):** shared electrons in a bond.
- branch chain (132):** a smaller chain of carbon atoms joined to the parent chain.
- branched-chain structure (132):** structure of organic compounds in which the carbon atoms are *not* all joined to each other in a single 'line'.
- buckminsterfullerene (108):** the first fullerene compound to be discovered, commonly called a buckyball.
- buckyball (108):** common name for buckminsterfullerene.



SAMPLE
GLOSSARY