Surfing

VCE CHEMISTRY 4

Unit 4 How Are Organic Compounds Categorised, Analysed and Used?

Marilyn Schell • Margaret Hogan

Science Press

First published 2017

Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

Introduction

This book covers the Chemistry content specified in the Victorian Certificate of Education Chemistry Study Design. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

SURFING

VCE CHEMISTRY 4

Area of Study 1

How Can the Diversity of Carbon Compounds Be Explained and Categorised?

1 The Element Carbon

Carbon is a non-metal element. Its atomic number is 6 because it contains 6 positively charged protons in the nucleus of each atom. There are also 6 negatively charged electrons orbiting the nucleus, with two electrons in the first shell and four electrons in the outer shell. So the electron configuration of carbon is 2.4 and it has a valence of 4.

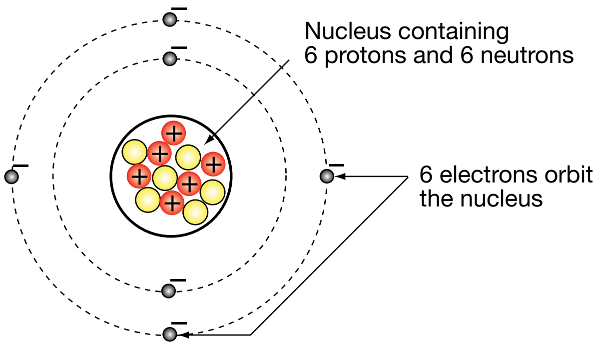


Figure 1.1 Atom of carbon-12.

Carbon is a special element because of the millions of compounds it can form and because carbon compounds are important constituents of living as well as non-living things.

The huge number of carbon compounds in existence is due largely to its ability to form strong bonds with other carbon atoms, making **chains and rings**, and also the stable bonds it can form with other elements.

Bonding of carbon atoms

Carbon atoms bond to each other by **sharing electrons**, forming strong covalent **carbon-carbon bonds**. You saw this last year when you studied carbon allotropes – diamond, graphite and fullerenes.

You will recall that carbon-carbon bonds can be single, double or triple bonds. Single bonds are the most common.

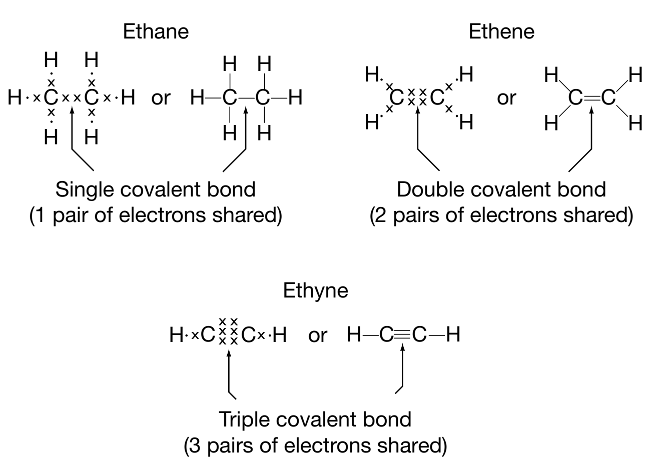


Figure 1.2 Single, double and triple C–C bonds.

Note: Although the electrons in all atoms are identical, they are sometimes illustrated as crosses and dots as in Figure 1.2 to show that the two electrons in a bond come from different atoms.

These are all strong covalent bonds and they increase in strength from single C–C bonds to double C=C bonds, with the shortest and strongest being triple C≡C bonds.

Table 1.1 Bond energies between carbon atoms.

Bond	Bond energy (kJ mol^{-1})
Single bond: C–C	348
Double bond: C=C	614
Triple bond: C≡C	839

Carbon also bonds with other elements. It forms strong **covalent bonds with hydrogen atoms**. These are considered to be non-polar bonds as the electronegativity difference between the atoms involved is very small.

Carbon also forms stable **polar bonds with oxygen, nitrogen, phosphorus and the halogens**.

You already know that the strength of these bonds varies with such factors as length of bonds (strength increases as length decreases) and differences in electronegativity (strength increases as electronegativity difference increases). For example, bond energy between carbon and the halogens decreases down the halogen group.

Table 1.2 Bond energies between carbon and some other atoms. (These vary slightly in different sources.)

Bond	Bond energy (kJ mol^{-1})
C–H	414
C–O	358
C–N	305
C–F	485
C–Cl	339
C–I	238

QUESTIONS

1. (a) Outline the position of carbon on the periodic table and state its electron configuration.
   (b) How many valence electrons are present in each atom of carbon?
2. List four factors that contribute to the huge number of carbon compounds that exist.
3. (a) Describe the type of bonding that occurs between carbon atoms.
   (b) Distinguish between single, double and triple carbon-carbon bonds.
4. (a) Name three other elements that bond to carbon atoms.
   (b) Identify two factors than can determine the strength of the bonds between atoms of carbon and other elements.

2 Organic Chemistry

Organic chemistry is the chemistry of carbon and its compounds. Carbon compounds are involved in our everyday life – the food we eat, fuels we burn, our own structure, and the polymers that we use to make everything from clothing to cars – all of these are carbon compounds.

Figure 2.1 Carbon fibre is used in car bodies.

Organic compounds make up over 80% of all known compounds and this does not include compounds such as carbon oxides and carbonates. Organic chemicals include the homologous series of alkanes and alkenes that you learned about in year 11 as well as many other groups of carbon compounds which are involved in everyday life such as alcohols, proteins, fats, carbohydrates, polymers and many more.

You will recall that alkanes and alkenes have functional groups (C–C for alkanes, C=C for alkenes). In this section you will be looking at more series of organic molecules that have other functional groups attached – the alcohols, carboxylic acids, esters, amines and amides. You will be seeing how the molecular structure of organic compounds and also the presence of functional groups are related to their properties. Later you will be looking at structures of proteins, carbohydrates and polymers.

The two scientists most influential in the initial development of carbon chemistry were a German chemist **August Kekulé** (1829-1896) and a Scottish chemist **Archibald Scott Couper** (1831-1892). Based on their observations of reactions, these two chemists independently developed a theory of how carbon formed bonds. They proposed that carbon was tetravalent (valency of 4) and described carbon atoms linking to each other, as well as to other atoms, and forming chains and rings.

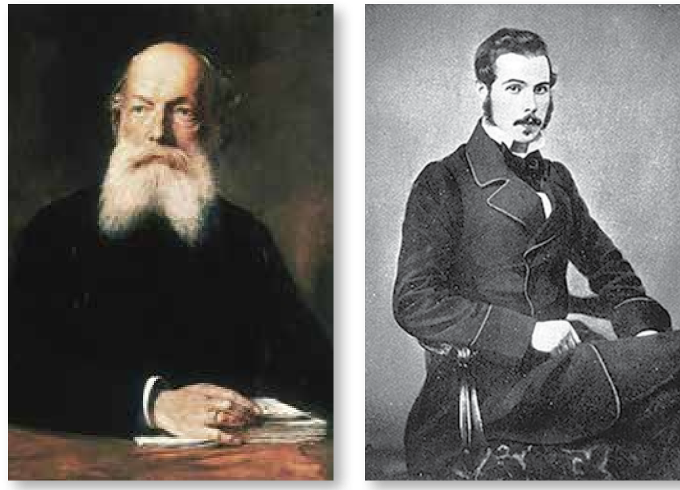


Figure 2.2 August Kekulé and Archibald Couper.

Their work represents the beginning of the concept of bonds between the elements in a compound, and they developed their ideas before anything was known about the attractions between atoms forming bonds.

Today the atomic model and models of bonding are used to explain the structure and properties of both elements and compounds. Models and theories of the structure of molecules have developed using evidence from a range of sources. And they can be used to explain and predict the properties of substances.

Data from analytical techniques such as mass spectrometry and crystallography have given us a deeper understanding of bonding and the chemical structure of carbon compounds and we classify organic molecules according to the functional groups that they contain. Conversely, if we know the formula of an organic compound then we can predict its chemical behaviour based on what we know about the behaviour of the functional groups it contains.

Functional groups

A **functional group** is a specific group of atoms, within a molecule, that is responsible for the chemical reactions of that molecule.

Functional groups are attached to the hydrocarbon 'backbone' of organic molecules. Figure 2.3 gives some examples of functional groups in organic compounds. You need to learn these.

The hydrocarbon backbone of organic compounds is represented by R in general formulas. An R can be added to the functional groups to indicate the position of any attached hydrocarbon chain. If there is more than one hydrocarbon chain, the chains are shown as R^1, R^2, R^3. Alternatively dashes may be used, e.g. R′, R″, R‴.

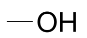
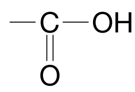
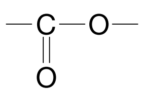
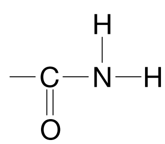
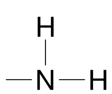
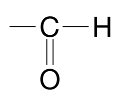
Alcohol	Carboxylic acid
 Alcohol functional group General formula of compound: R–OH	 Carboxylic acid functional group General formula of compound: R–COOH
Ester	**Amide**
 Ester functional group General formula of compound: R^1–COO–R^2	 Amide functional group General formula of compound: R–CO–NH_2
Amine	**Aldehyde**
 Amine functional group General formula of compound: R–NH_2	 Aldehyde functional group General formula of compound: R–CHO

Figure 2.3 Functional groups.

Homologous series

Organic compounds containing only carbon and hydrogen atoms are called **hydrocarbons**. Each family of hydrocarbons is called an **homologous series**.

Homologous means that all members of a series have something in common – they share a **general formula** and a special feature or **functional group** (a grouping of atoms that is common to all members of that series).

There are three homologous series of hydrocarbons:

- Alkanes have only single –C–C– bonds.
- Alkenes contain at least one double –C=C– bond.
- Alkynes contain one or more triple –C≡C– bond.

Table 2.1 Three homologous series.

Homologous series	General formula	Functional group
Alkane	C_nH_{2n+2}	–C–C– Single bonded carbon atoms
Alkene	C_nH_{2n}	–C=C– Double bonded carbon atoms
Alkyne	C_nH_{2n-2}	–C≡C– Triple bonded carbon atoms

A lot of the work covered in this topic will be revision from year 11. To make it easier for you, we will repeat the relevant sections from Surfing VCE Chemistry Unit 1 in this book.

Alkyl group

Another term you should recall is an **alkyl group**. This refers to a hydrocarbon chain with the general formula C_nH_{2n+1}. An example is a methyl group (–CH_3). This is a fragment of a methane molecule (CH_4). Alkyl groups do not exist on their own, they are branches of carbon molecules.

Table 2.2 Alkyl groups.

Alkane	Formula	Alkyl group	Formula
Methane	CH_4	Methyl group	–CH_3
Ethane	CH_3CH_3	Ethyl group	–CH_2CH_3
Propane	$CH_3CH_2CH_3$	Propyl group	–$CH_2CH_2CH_3$ or –C_3H_7

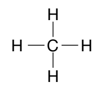
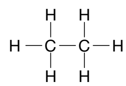
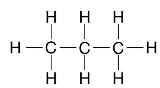
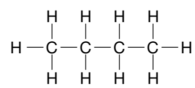
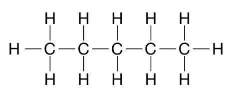
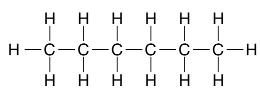
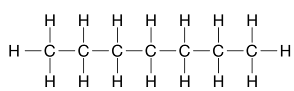
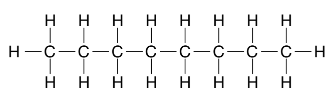
QUESTIONS

1. (a) Define organic chemistry.
   (b) Name five examples of organic compounds.
2. Identify two chemists influential in the initial development of carbon chemistry.
3. (a) Define a functional group.
   (b) Recall the functional group for an alkene, an alcohol and a carboxylic acid.
4. What does IUPAC stand for?
5. (a) What is meant by a general formula?
   (b) Distinguish between the general formula for an alkane and an alkene.
6. What is meant by an homologous series? Include an example in your answer.
7. (a) What is meant by an alkyl group?
   (b) Distinguish between butane and butyl.
8. Check your knowledge with this quick quiz.
   (a) Hydrocarbons with single C–C bonds are called (alkanes/alkenes).
   (b) The stem (prefix) of a carbon compound with four carbon atoms would be named ....
   (c) The carbon atom attached to a functional group is numbered so that it has the (lowest/highest) possible number.
   (d) State the general formula for an alkane.
   (e) The symbol R–OH is the general formula for an ....
   (f) Which part of the name of a compound tells you the functional group present?
   (g) What is the stem (prefix) of an alkane with two carbon atoms present?

3 Hydrocarbons – Alkanes

The following table shows the first eight alkanes.

Table 3.1 Alkanes.

Name of alkane	Molecular formula	Structural formula
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	
Hexane	C_6H_{14}	
Heptane	C_7H_{16}	
Octane	C_8H_{18}	

- Molecules increase in size by a CH_2 grouping each step down a series. General formula C_nH_{2n+2}.
- Alkanes are saturated hydrocarbons – they contain only single carbon-carbon bonds.
- Alkanes are described as non-polar as there is no net charge on each molecule.
- Intramolecular bonds (within the molecule) are strong covalent bonds.
- Intermolecular bonds (between molecules) are weak dispersion forces. These are broken when the alkane changes state (melts or boils). C1 to C4 have the lowest boiling points. Larger molecules have higher boiling points because dispersion forces increase as the mass of the molecule increases.
- At 25°C and 100 kPa pressure, alkanes from C1 to C4 are gases, C5 to C20 are liquids and those with larger molecules are soft solids.

Naming alkanes

Carbon compounds are named systematically using IUPAC naming. IUPAC stands for the International Union of Pure and Applied Chemistry.

- The prefix or stem of the name indicates the number of carbon atoms that form the longest continuous chain. For example, meth– C_1, eth– C_2, prop– C_3, but– C_4, pent– C_5, hex– C_6, hept– C_7, oct– C_8.
- The **end of the name (suffix)** indicates the series to which the compound belongs. For example, ... ane indicates an alkane with single C–C bonds.

Cyclohexane

Some carbon compounds exist as ring structures. An example is cyclohexane, which is a cycloalkane with molecular formula C_6H_{12}.

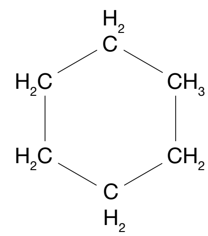
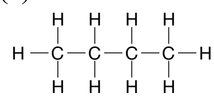
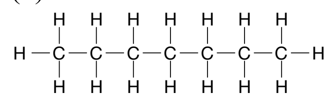


Figure 3.1 Cyclohexane.

Cyclohexane is a clear, colourless, flammable liquid which is used as a solvent and in the manufacture of nylon.

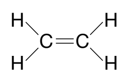
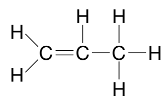
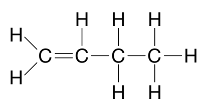
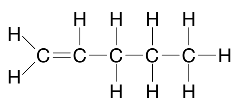
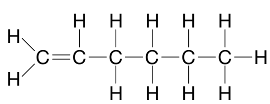
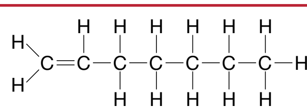
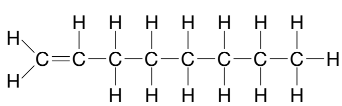
QUESTIONS

1. Draw structural and semi-structural formulas for:
   (a) Propane. (b) Octane. (c) Methane.
2. Write molecular formulas for:
   (a) Ethane. (b) Pentane. (c) Hexane.
3. Name the following compounds.
   (a)  (b) 
4. (a) State the general formula for an alkane.
   (b) Identify three alkanes that occur naturally as gases.
5. (a) Justify the application of the term 'homologous series' to alkanes.
   (b) Describe how you have modelled the structure of alkanes. Use a diagram to show one model of a named alkane.
   (c) Draw a diagram of two molecules of ethane and label them to show intramolecular covalent bonds and intermolecular dispersion forces.

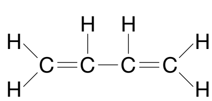
4 Hydrocarbons – Alkenes

Alkenes are an homologous series of hydrocarbons with the general formula C_nH_{2n}. Each alkene has a **carbon-carbon double bond**, so alkenes are described as **unsaturated**. The double bond makes alkenes **more reactive** than alkanes.

Table 4.1 The first seven alkenes.

Name	Molecular formula	Structural formula
Ethene	C_2H_4	
Propene	C_3H_6	
But-1-ene	C_4H_8	
Pen-1-tene	C_5H_{10}	
Hex-1-ene	C_6H_{12}	
Hept-1-ene	C_7H_{14}	
Oct-1-ene	C_8H_{16}	

- Notice that methene does not exist. You cannot have a double bond between two carbon atoms if the molecule only contains one carbon atom.
- If two double bonds are present in a hydocarbon, it is called a diene, for example buta-1,3-diene.



Uses of alkenes

Because alkenes are more reactive than alkanes they are widely used in industry. For example:

Ethene (ethylene) is widely used in the petrochemical industry, in the manufacture of such things as polymers, cosmetics, detergents, brake fluid and antifreeze.

Propene is used in the manufacture of polypropylene, glycerine and nitroglycerine.

Cycloalkenes

Alkenes can form cyclic compounds such as cyclohexene. Cyclohexene is a clear, colourless liquid which is insoluble in water and less dense than water.

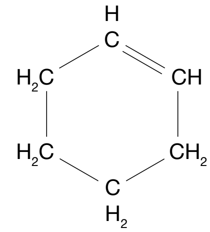
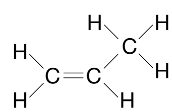
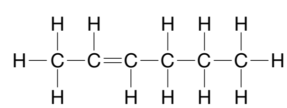
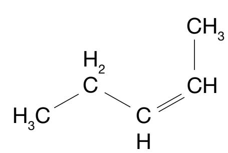


Figure 4.1 Cyclohexene (C_6H_{10}).

QUESTIONS

1. (a) State the general formula for an alkene.
   (b) Use this general formula to determine the molecular formula of:
      (i) An alkene with 11 carbon atoms per molecule.
      (ii) An alkene with 34 hydrogen atoms per molecule.
   (c) Identify the functional group for alkenes.
   (d) Are alkenes saturated or unsaturated compounds?
2. Name the following alkenes.
   (a)
   
   (b)
   
   (c) C_6H_{12}
   (d)
   
3. Write molecular, semi-structural (condensed) and structural formulas for the following compounds.
   (a) Prop-2-ene.
   (b) But-1-ene.
   (c) Hept-3-ene.
   (d) Hex-3-ene.

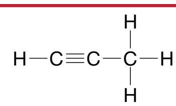
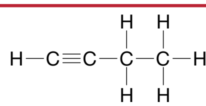
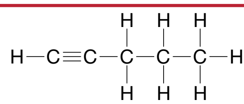
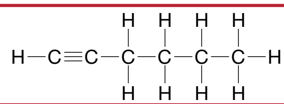
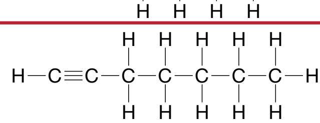
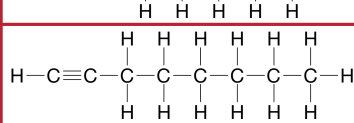
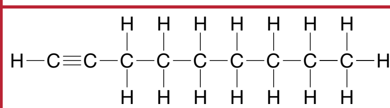
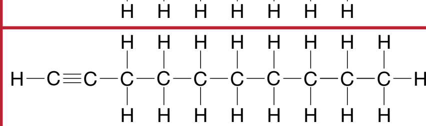
5 Hydrocarbons – Alkynes

Alkynes are a homologous series of hydrocarbons with the general formula C_nH_{2n-2}. Each alkyne has one or more **carbon-carbon triple bonds**.

Alkynes are described as **unsaturated** because of the presence of triple bonds and, like alkenes, they are **more reactive** than alkanes.

The following table shows the first nine alkynes. Notice methyne does not exist.

Table 5.1 Alkynes.

Name	Molecular formula	Structural formula
Ethyne	C_2H_2	H—C≡C—H
Propyne	C_3H_4	
Butyne	C_4H_6	
Pentyne	C_5H_8	
Hexyne	C_6H_{10}	
Heptyne	C_7H_{12}	
Octyne	C_8H_{14}	
Nonyne	C_9H_{16}	
Decyne	$C_{10}H_{18}$	

Alkynes are named in a similar way to alkenes. The ending –yne indicates the presence of a triple bond. A number before the name indicates the position of the triple bond. As for alkenes, you number from whichever end gives the smallest number (see Figure 5.1).

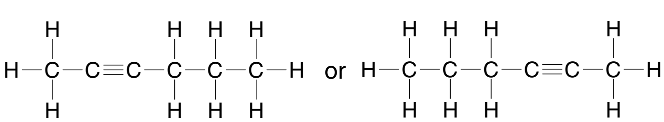


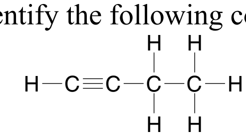
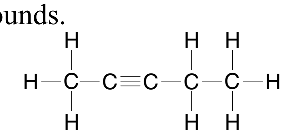
Figure 5.1 2-Hexyne (or hex-2-yne).

Ethyne (C_2H_2) is commonly called acetylene and is used as a fuel. Acetylene produces a high temperature flame and it is used in oxyacetylene torches to cut and weld metals. Ethyne changes from a solid to a gas at –84°C without becoming a liquid. That is, it sublimes.

QUESTIONS

1. Identify the following.
   (a) Molecular formula for ethyne.
   (b) Structural formula for ethyne.
   (c) Common name for ethyne.
2. Explain what is meant by:
   (a) Alkyne. (b) Triple bond. (c) Sublimes.
3. Complete the following table to compare ethane, ethene and ethyne.

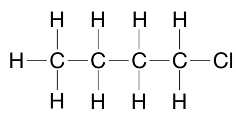
Factor	Ethane	Ethene	Ethyne
Formula			
Boiling point (°C)	–89	–104	–84 (sublimes)
Homologous series			
Common feature			
Difference in reactivity			
Saturated/ unsaturated			
Uses			

4. Use the boiling points in the table in Question 3 to determine which of the three compounds, ethane, ethene or ethyne has the weakest dispersion forces. Justify your answer.
5. Justify the classification of alkanes, alkenes and alkynes as hydrocarbons.
6. Identify the following compounds.
   (a)  (b) 
   (c) $CHC(CH_2)_3CH_3$
7. For the compound 3-heptyne, write the:
   (a) Molecular formula. (b) Structural formula.
   (c) Condensed structural formula.
8. Check your knowledge with this quick quiz.
   (a) Hydrocarbons with a triple bond belong to which homologous series?
   (b) In a triple bond, ... electrons are shared.
   (c) Name the alkyne with three carbon atoms.
   (d) Write the molecular formula for the alkyne with five carbon atoms.
   (e) Identify the systematic name for acetylene.
   (f) State the functional group of the alkynes.
   (g) How many carbon atoms in heptyne?
   (h) Are alkynes saturated or unsaturated?

6 Haloalkanes

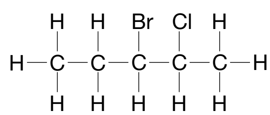
Halogens are elements found in group 7 (17) of the periodic table, the most common being fluorine, chlorine, bromine and iodine.

When a halogen atom becomes substituted into an alkane, the compound is called a **haloalkane**, for example, 1-chlorobutane.



To name haloalkanes, follow these brief rules.

- Use prefixes for the halogen, e.g. fluoro, chloro, bromo or iodo.
- If more than one halogen atom is present in the molecule, then list them in alphabetical order.
- Number the carbon with the halogen attached, giving preference to any double bond, otherwise giving the lowest number to the halogen group, for example 3-bromo-2-chloropentane.



3-bromo-2-chloropentane

Haloalkanes can be primary, secondary or tertiary, depending on the position of the halogen atom in the molecule.

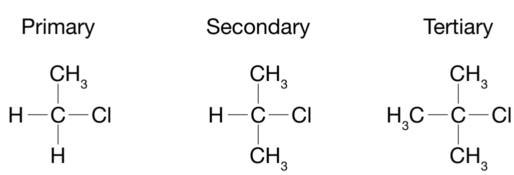


Figure 6.1 Primary, secondary and tertiary haloalkanes.

You can see from Figure 6.1 that in a **primary haloalkane**, the carbon to which the halogen is attached only has one other attached alkyl group, e.g. CH_3CH_2Br. Methyl halides such as CH_3Cl have no alkyl groups attached to the C atom attached to the halogen, but these are also considered to be primary haloalkanes.

The bond between the halogen and carbon atoms is **polar covalent** because there is a large difference in electronegativity between the two atoms, for example chloromethane. As this bond is not balanced, the molecule will be polar so there will be dipole-dipole forces of attraction as well as dispersion forces holding molecules together. Stronger intermolecular forces lead to higher boiling and melting points.

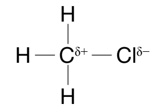


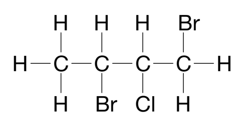
Figure 6.2 Polar bond in chloromethane.

Haloalkanes are not very soluble in water, but are more soluble in organic solvents. Haloalkanes tend to be more dense than alkanes and also more dense than water.

Note that a halogen attached to an alkene or an alkyne forms a haloalkene and a haloalkyne. In this case, preference is given to the double or triple bond when numbering.

QUESTIONS

1. What is meant by a haloalkane?
2. Research more details about the naming of haloalkanes.
3. Name the following compounds.
   (a) CH_3CH_2Cl
   (b) $C_6H_{13}I$
   (c)



4. Draw structural formulas for the following haloalkanes.
   (a) 1,2-Dibromoethane.
   (b) A haloalkane with 4 carbon atoms and 1 chlorine atom on C1.
   (c) 1,1,2-Trichlorobutane.
   (d) 2-Bromo-3-fluoro-2-iodopentane.
5. Graph the following information about the boiling points of haloalkanes and outline the trends illustrated by the graphs.
   (a)

Chemicals	Boiling points (°C)
CH_3CH_2F	–37.7
CH_3CH_2Cl	12.3
CH_3CH_2Br	38.4
CH_3CH_2I	72.3

   (b)

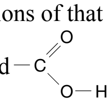
Chemicals	Boiling points (°C)
CH_3CH_2Cl	12.3
$CH_3CH_2CH_2Cl$	46.6
$CH_3CH_2CH_2CH_2Cl$	78.4
$CH_3CH_2CH_2CH_2CH_2Cl$	107.8

Answers

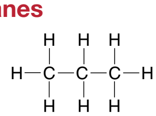
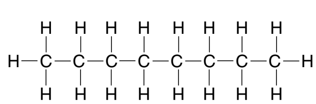
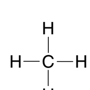
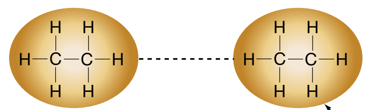
1 The Element Carbon

1. (a) Atomic number 6, group 4, period 2, electron configuration 2.4.
   (b) 4
2. Carbon has four valence electrons; it can bond with other carbon atoms to form rings and chains of carbon atoms; it can form single, double and triple bonds; it can form stable bonds with many other elements.
3. (a) Carbon-carbon bonds are strong, stable covalent bonds. They can be single, double or triple bonds, of which triple bonds are the shortest and strongest.
   (b) A single carbon-carbon bond involves the sharing of 2 valence shell electrons.
   A double bond involves the sharing of 4 (2 pairs) valence shell electrons.
   A triple bond involves 2 carbon atoms sharing 6 (3 pairs) valence shell electrons.
4. (a) Various, e.g. oxygen, nitrogen, sulfur, chlorine, iodine, fluorine, bromine.
   (b) The length of the bond and the difference in electronegativity of the bonding elements.

2 Organic Chemistry

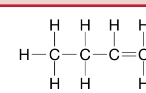
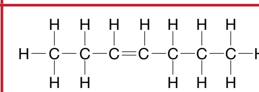
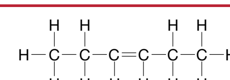
1. (a) Organic chemistry is the study of carbon and its compounds.
   (b) Various, e.g. sucrose, alkanol, starch, ethanol, glucose, any alkane, e.g. ethane, any alkene, e.g. ethene.
2. August Kekulé and Archibald Couper.
3. (a) A functional group is a specific group of atoms within a molecule that is responsible for the chemical reactions of that molecule.
   (b) Alkene a C=C bond. Alcohol –OH. Carboxylic acid 
4. IUPAC stands for International Union of Pure and Applied Chemistry.
5. (a) A general formula is one which applies to all the compounds in an homologous series.
   (b) Both are hydrocarbons. Alkanes have more hydrogen atoms per carbon atom than alkenes – alkanes are saturated and alkenes are unsaturated. Alkane – C_nH_{2n+2} and alkene C_nH_{2n}.
6. An homologous series is a group of compounds which all have the same functional group, e.g. alkanes, alkenes, alcohols.
7. (a) An alkyl group is part of an organic molecule that has the general formula C_nH_{2n+1}. For example, a methyl group CH_3, an ethyl group CH_3CH_2 or a butyl group C_4H_9.
   (b) Butane is the alkane C_4H_{10}. Butyl is the alkyl group of butane, with formula $–C_4H_9$.
8. (a) Alkanes. (b) But-
   (c) Lowest. (d) C_nH_{2n+2}
   (e) Alcohol. (f) Suffix.
   (g) Eth-

3 Hydrocarbons – Alkanes

1. (a) $CH_3CH_2CH_3$ 
   (b) $CH_3(CH_2)_6CH_3$ 
   (c) CH_4 
2. (a) C_2H_6
   (b) C_5H_{12}
   (c) C_6H_{14}
3. (a) Butane
   (b) Heptane
4. (a) C_nH_{2n+2}
   (b) Methane, ethane, propane.
5. (a) Homologous series is a group of carbon compounds which have a general formula and functional group. Alkanes are a series of hydrocarbons with a general formula C_nH_{2n+2} and all alkanes have single C–C bonds as the functional group.
   (b) Various. You may have used model kits or materials such as plasticene or foam balls. Use a diagram to show the 3-D structure of one of the alkanes you modelled.
   (c) 

4 Hydrocarbons – Alkenes

1. (a) C_2H_{2n}
   (b) (i) $C_{11}H_{22}$
   (ii) $C_{34}H_{68}$
   (c) One or more double C=C bonds present in the molecule.
   (d) Alkenes are unsaturated as they contain one or more double C=C bonds; they do not have the maximum number of hydrogen atoms in their molecules.
2. (a) Propene.
   (b) Hex-2-ene.
   (c) Hexene. *Note:* The molecular formula does not indicate the position of the double bond.
   (d) Pent-2-ene.
3. (a) Prop-2-ene does not exist – it would be the same as prop-1-ene, just numbered from the opposite end.

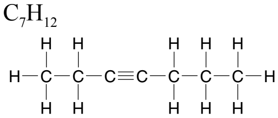
	Molecular formula	Semi-structural formula	Structural formula
(b) But-1-ene	C_4H_8	$CH_3–CH_2–CH=CH_2$	
(c) Hept-3-ene	C_7H_{14}	$CH_3(CH_2)_5CH_3$	
(d) Hex-3-ene	C_6H_{12}	$CH_3CH_2CH=CHCH_2CH_3$	

5 Hydrocarbons – Alkynes

1. (a) C_2H_2
   (b) H—C≡C—H
   (c) Acetylene.
2. (a) Homologous series of hydrocarbons with a triple C≡C bond.
   (b) A bond formed by sharing three pairs of electrons between two atoms.
   (c) Changes from a solid to a gas without becoming a liquid.

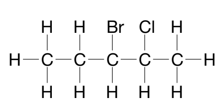
3.

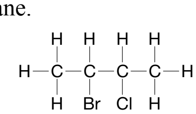
Factor	Ethane	Ethene	Ethyne
Formula	C_2H_6	C_2H_4	C_2H_2
Boiling point	–89	–104	–84 (sublimes)
Homologous series	Alkane	Alkene	Alkyne
Common feature	2 carbon atoms	2 carbon atoms	2 carbon atoms
Difference in reactivity	Least active	More active	More active
Saturated/ unsaturated	Saturated	Unsaturated	Unsaturated
Uses	Fuel in natural gas. Manufacture of ethene.	Manufacture of polymers.	Fuel in oxyacetylene torches.

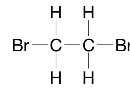
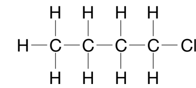
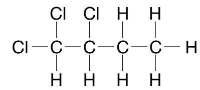
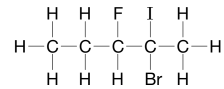
4. Ethene has the lowest boiling point. This indicates that least energy is needed to break the dispersion forces between its molecules. So the dispersion forces of ethene are weaker than those of ethane or ethyne.
5. They all contain carbon and hydrogen only, hence are called hydrocarbons.
6. (a) 1-Butyne or but-1-yne.
   (b) 2-Pentyne or pent-2-yne.
   (c) 1-Hexyne or hex-1-yne.
7. (a) C_7H_{12}
   (b) 
   (c) $CH_3CH_2CC(CH_2)_2CH_3$
8. (a) Alkynes.
   (b) 6 (3 pairs)
   (c) Propyne.
   (d) C_5H_8
   (e) Ethyne.
   (f) Triple C≡C bond.
   (g) 7
   (h) Unsaturated.

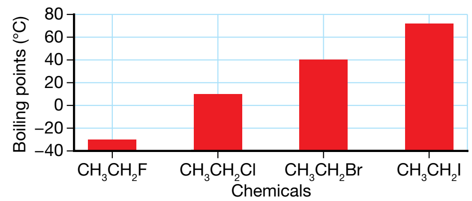
6 Haloalkanes

1. A haloalkane is an alkane which has one or more hydrogen atoms replaced by halogen atoms.
2. Naming of haloalkanes:
   - Identify the alkane chain according to the number of carbon atoms in the molecule, e.g. ethane, pentane.
   - Use a prefix, e.g. bromo, chloro, fluoro or iodo to identify any halogen present in the molecule. If more than one halogen is present, list them in alphabetical order.
   - If there is more than one atom of any halogen, then add the appropriate prefix, e.g. di-, tri- or tetra- in front of the halogen name. For example, dichloro would indicate the presence of two chlorine atoms in the molecule.
   - Ignore the di, tri, tetra prefixes when naming in alphabetical order. For example, dibromo would come before chloro.
   - Number the carbons, in the alkane chain, with the halogens attached, using the lowest possible number or set of numbers. For example, this compound would be named 3-bromo-2-chloropentane, *not* 3-bromo-4-chloropentane.

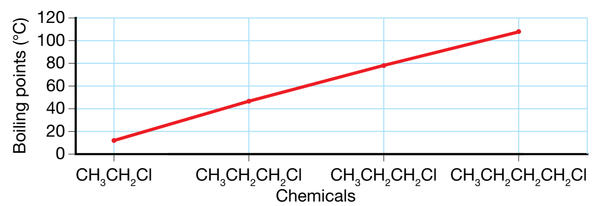
     
     3-bromo-2-chloropentane
   - Use commas between numbers and hyphens between numbers and names, e.g. 1,2-dichlorobutane.
   - If the numbering of the chain gives the same set of numbers when starting from both ends, then give the first named halogen the lowest number. For example:

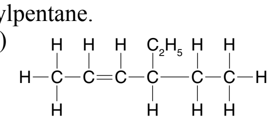
     The correct name is 2-bromo-3-chlorobutane, *not* 3-bromo-2-chlorobutane as the lowest number is given to bromo because it comes before chloro alphabetically.
3. (a) Chloroethane.
   (b) Iodohexane. (*Note*: The molecular formula gives no indication as to where the iodine atom is attached.)
   (c) 1,3-dibromo-2-chlorobutane.
4. (a) 
   (b) 
   (1-chlorobutane, a primary haloalkane)
   (c) 
   (d) 
5. (a) This graph shows that the boiling points of haloalkanes depend on the actual halogen present in the molecule. For molecules of the same length, the boiling point is lowest for haloalkanes with fluorine, e.g. −37.7°C for fluoroethane, and increases for Cl, Br and I. It is highest for iodoalkane at 72.3°C.

   (b) This graph shows that boiling points of haloalkanes are affected by the length of the carbon chain. If the same halogen is present, the boiling point increases as the chain becomes longer. For example, the boiling point of chloroethane is 12.3°C and increases to 107.8°C for chlorobutane.

7 Naming Hydrocarbons

1. (a) 2-Methylbutane. (b) 4-Methyl-hex-2-ene.
   (c) Pent-2-yne. (d) 2,4-Dimethyl-pentane.
   (e) 3-Ethyl-pent-1-ene. (f) 3-Ethyl-2,2-dimethylhexane.
   (g) 3-Chloro-but-1-yne.
2. (a) The correct name is 3-methylheptane. The longest chain is bent and it is 7 C's long, not 6, making it heptane. There is one methyl group attached to the third carbon in the chain.
   (b) The longest carbon chain has 5 C's not 4 as it is bent. Its correct name is 2,3-dimethylpentane.
3. (a) $H_3C-C\equiv C-Cl$
   (b) 
4. (a) 2-Bromo-2-methylpropane.
   (b) 3-Chloro-2-methylprop-1-ene.
   (c) 2-Methyl-2-butene.

8 Structural Isomers

1. (a) Structural isomers are molecules with the same molecular formula but different arrangements of the atoms in space.
   (b) • Chains can be straight or they can branch in different ways.
   • The basic chain stays the same, but attached groups such as a chlorine atom, or a hydroxyl group can be attached at different positions.
   • Atoms are arranged in different ways that lead to the isomers belonging to different homologous series.