St Ninian's High School

Chemistry Department

National 5 Chemistry

Unit 2: Nature's Chemistry

Topic 1

Hydrocarbons

Summary Notes

Name_____

Learning Outcomes

After completing this topic you should be able to :

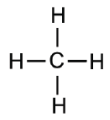
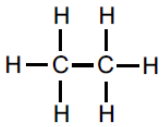
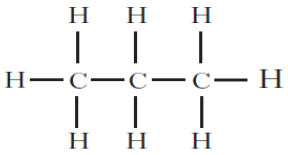
1 state that a hydrocarbon is a compound made of hydrogen and carbon only
2 state that the alkanes, alkenes and cycloalkanes are each a subset of the set of hydrocarbons
3 identify an alkane from the -ane ending
4 name straight-chain alkanes from molecular formulae shortened and full structural formulae (C_1 - C_8)
5 write molecular formulae and draw shortened and full structural formulae given the names of straight-chain alkanes (C_1 - C_8)
6 derive and use the general formula for alkanes to work out molecular formulae
7 state that a homologous series is a set of compounds with the same general formula and similar chemical properties
8 explain that the alkane, alkene and cycloalkanes families are each an example of a homologous series
9 name branched-chain alkanes from shortened and full structural formula (only C_4 - C_8)
10 write molecular formulae and draw shortened and full structural given the systematic names of branched-chain alkanes (only C_4 - C_8)
11 identify an alkene from the –ene ending and the carbon to carbon double bond
12 state the name for each alkene up to octene and work out names from molecular, shortened or full structural formulae (C_2 - C_8)
13 state the name for straight and branched chain alkenes, incorporating the position of the double bond, from shortened and full structural formulae (C_2 - C_8)
14 derive and use the general formula for alkenes to work out molecular formulae
15 identify a cycloalkane from the name
16 name cycloalkanes from molecular formulae, shortened and full structural formulae (C_3 - C_8)
17 write molecular formulae and draw shortened and full structural given the names of cycloalkanes (only C_3 - C_8)
18 state that isomers are compounds with the same molecular formulae but different structural formulae
19 draw isomers for a given molecular formulae, shortened and full structural formulae
20 state that the alkanes and cycloalkanes are saturated hydrocarbons
21 state that saturated hydrocarbons contain only single carbon to carbon covalent bonds
22 state that the alkenes are unsaturated since they contain at least one carbon to carbon double covalent bond
23 state it is possible to distinguish an unsaturated hydrocarbon from a saturated hydrocarbon using bromine solution
24 state that an alkene reacts with hydrogen to form the corresponding alkane
25 state that the reactions of an alkene with bromine, hydrogen and water (hydration) are addition reactions.

Hydrocarbon Families

A **hydrocarbon** is a compound which contains **only** carbon and hydrogen.

The Alkanes

The alkanes are the simplest family of hydrocarbons. In an alkane molecule each carbon atom, (valency = 4) is covalently bonded to four other atoms. Methane, with molecular formula CH_4, is the simplest and smallest alkane molecule. It contains just one carbon atom and four hydrogen atoms. Methane is a useful fuel and is used as gas in homes and in school. Methane is found in natural gas which is an example of a fossil fuel. All alkanes have a name which ends in -ane.

Name of Alkane	No of C atoms in molecule	Molecular Formula	Full Structural Formula
methane	1	CH_4	
ethane	2	C_2H_6	
propane	3	C_3H_8	

The alkanes are methane, ethane, propane, butane, pentane, hexane, heptane and octane.

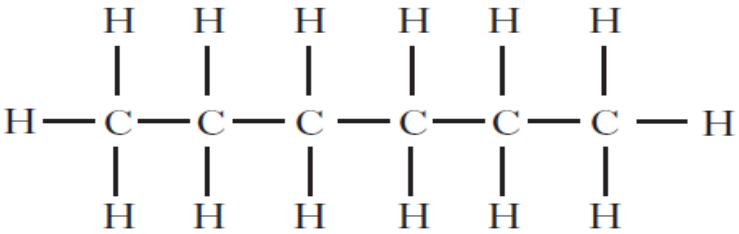
Shortened Structural Formulae

The shortened structural formula can be used to show the grouping of hydrogen atoms round each carbon atom. A shortened structural formula is sometimes a more convenient way to represent a molecule.

Example: Hexane

Hexane has the chemical formula C_6H_{14}.

Full structural formula for hexane is



Shortened structural formula for hexane is $CH_3CH_2CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_4CH_3$

Hydrocarbon Families

A General Formula

The alkanes are the simplest family of hydrocarbon molecules. The general formula for the alkanes is therefore:

$$C_nH_{2n+2}$$

All alkanes have a molecular formula which will match the general formula. A general formula is used to represent the overall formula for a group of compounds.

Homologous Series

Having looked at the alkanes in a little detail you know that this family of compounds can be represented by a general formula and have gradual changing boiling points. In addition to gradually changing boiling points the alkanes also have similar chemical properties which means they react in a similar way for example they burn to produce carbon dioxide and water.

The alkanes are an example of a **homologous series**. A homologous series is a family of compounds which

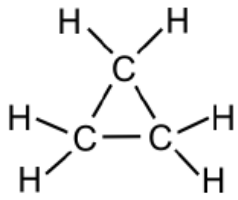
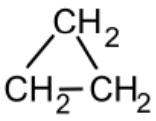
i) have the **same general formula**

ii) have **similar chemical properties** (take part in similar chemical reactions)

iii) have **gradual changing physical properties** e.g. melting & boiling points, colour, viscosity (thickness).

The Cycloalkanes

As well as forming chains, carbon atoms can also bond to form rings. Compounds whose molecules contain rings of carbon atoms with only single bonds are called cycloalkanes. The cycloalkanes are an example of a homologous series. The first cycloalkane is cyclopropane as shown in the table.

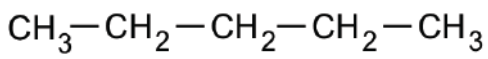
Full structural formula	Shortened structural formula	Formula
		C_3H_6

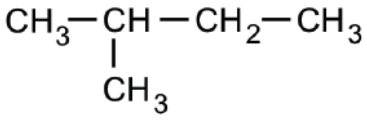
The general formula for the cycloalkanes is C_nH_{2n}.

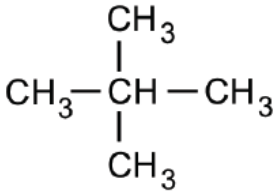
Branched Alkanes

So far we have only considered straight-chain alkanes where the carbon atoms are arranged one after another to give a straight-chain of carbon atoms. Branched alkane molecules also exist where there are one or more carbon atoms arranged as branches. Branched molecules are given a systematic name according to a convention.

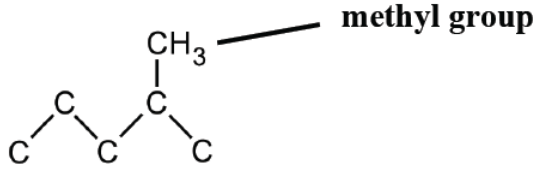
Consider the compound with molecular formula C_5H_{12}: there are several different molecules with this molecular formula. Note A is a **straight-chain** while B & C are **branched** chain molecules.

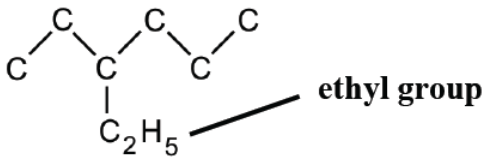
A 

B 

C 

Each molecule may have the same molecular formula but must be given a different name since the structure is different. Branches are named after the corresponding alkanes with the -ane ending changed to -yl.

e.g. 



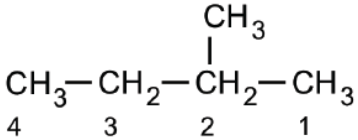
To name a branched molecule:

i) select the longest continuous chain of carbon atoms and name it after the appropriate alkane

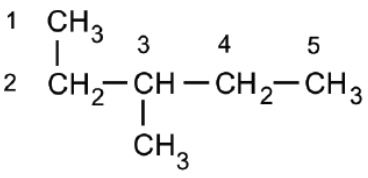
ii) number the carbon atoms from the end of the chain nearest to the branch

iii) name the branch(es) and indicate the position(s) of the branch(es) on the chain

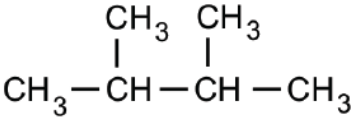
iv) use"di" and "tri", etc, when the same branch is present more than once.

e.g. 

2-methylbutane



3-methylpentane

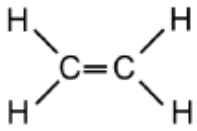


2,3-dimethylbutane

Hydrocarbon Families

The Alkenes

Both the alkanes and cycloalkanes contain only single carbon-to-carbon bonds. The **alkenes** are a family which contain one carbon-to-carbon double bond. The alkenes are another example of a homologous series. The first member of the alkene family is ethene (shown below) since at least 2 carbons are needed to have a double carbon-to-carbon bond, the molecule methene does not exist.

Full structural formula	Shortened structural formula	Formula
	$CH_2=CH_2$	C_2H_4

The general formula for the alkenes is $\mathbf{C_nH_{2n}}$.

For some alkane molecules a number is used to indicate the position of the double carbon-to-carbon bond e.g. but-1-ene and but-2-ene.

but-1-ene $CH_3-CH_2-CH=CH_2$

but-2-ene $CH_3-CH=CH-CH_3$

Branched Alkenes

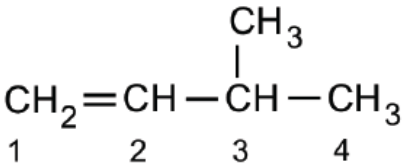
Alkenes, like alkanes, can also form branched chain molecules. Branched alkanes are named in a similar way to branched alkanes.

i) Select the longest continuous chain of carbon atoms containing the double bond and name it after the appropriate alkene.

ii) Number the carbon atoms from one end of the chain nearer the double bond and indicate the position of the double bond.

iii) Name any branch(es) and indicate the position(s) of the branch(es) on the chain.

Example:



3-methylbut-1-ene

Hydrocarbon Families

Saturated and Unsaturated Molecules

Hydrocarbon families are described as **saturated** if all the carbon-to-carbon bonds are single bonds. If the molecule contains any double (or triple) carbon-to-carbon bonds the molecules are referred to as **unsaturated**.

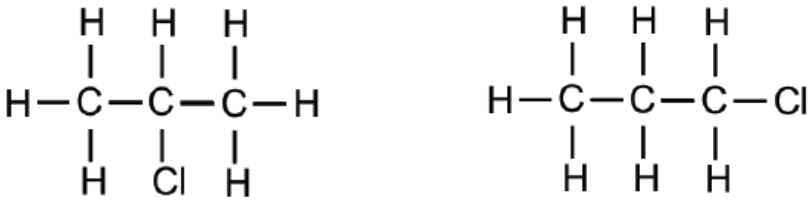
The alkanes and cycloalkanes are examples of saturated hydrocarbon families. The alkenes are an example of an unsaturated hydrocarbon family.

Isomers

Isomers are compounds with the same molecular formula but a different structural formula. In other words isomers are molecules which have the same atoms but attached in a different way.

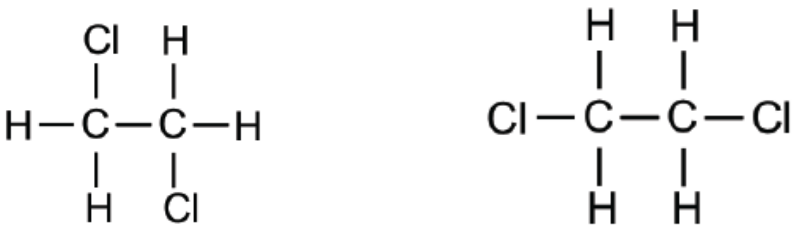
Example 1: C_3H_6Cl

Two different molecules can be created which have this molecular formula.



In this example the chlorine atom is attached in a different location to create isomers.

Example 2: $C_2H_4Cl_2$



The two molecules here have the same molecule formula and the same structure and are therefore **not** isomers. (The chlorine atoms are still attached in the same way.)

Hydrocarbon Reactions

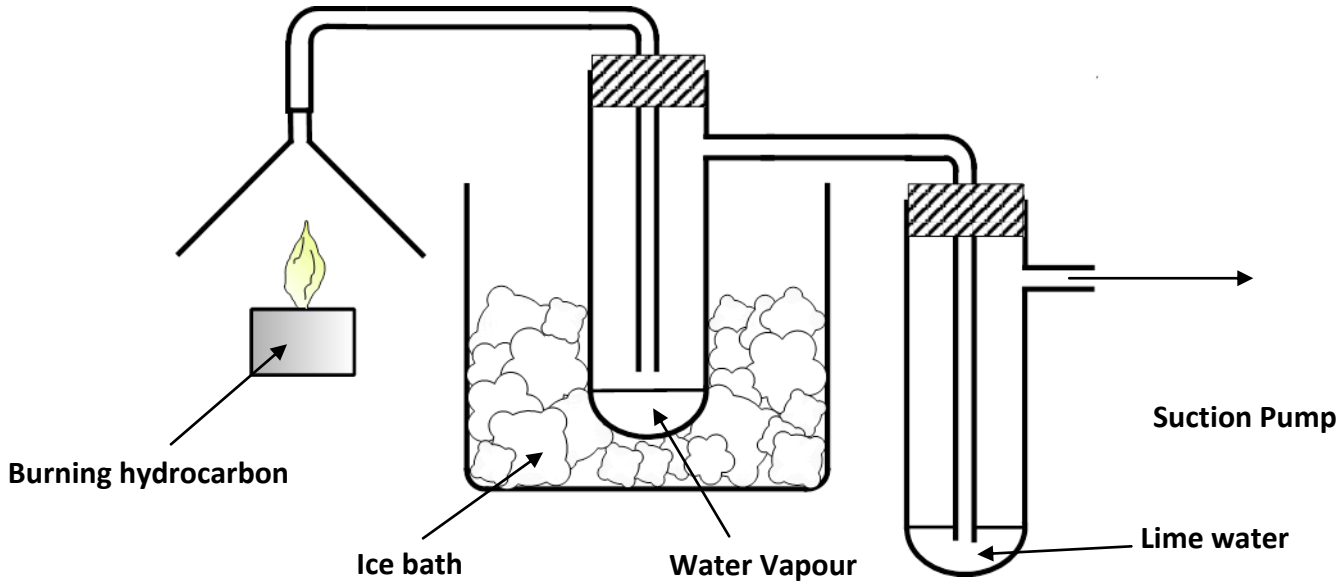
Combustion

The most common chemical reaction of the alkanes is combustion or burning. In a **combustion** reaction oxygen (usually from the air) reacts with an alkane to form carbon dioxide and water. Any hydrocarbon molecule will produce carbon dioxide and water if burned completely.

Combustion of Hydrocarbons

Complete Combustion

When a hydrocarbon burns in a plentiful supply of oxygen the products are carbon dioxide and water. The following apparatus can be used to show the products of complete combustion of a hydrocarbon.



In General:

Hydrocarbon	+	Oxygen (plentiful)	⟶	Water	+	Carbon dioxide

Incomplete Combustion:

Incomplete combustion occurs when there is insufficient oxygen. During incomplete combustion of a hydrocarbon carbon monoxide and carbon (soot) forms rather than carbon dioxide. Incomplete combustion occurs in a car engine due to the lack of air inside the engine.

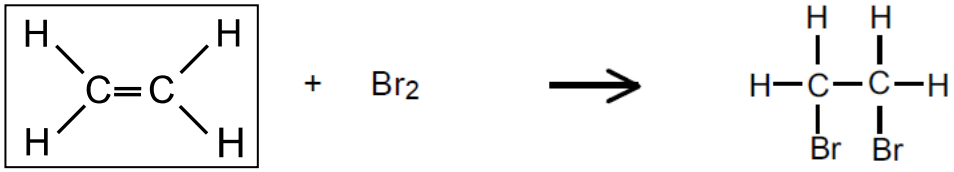
In General:

Hydrocarbon	+	Oxygen (limited)	⟶	Water	+	Carbon	+	Carbon monoxide

Hydrocarbon Reactions

Addition Reactions

Since alkene molecules are unsaturated they will react to produce saturated molecules in an addition reaction. For example ethene will react with bromine to form 1,2-dibromoethane.



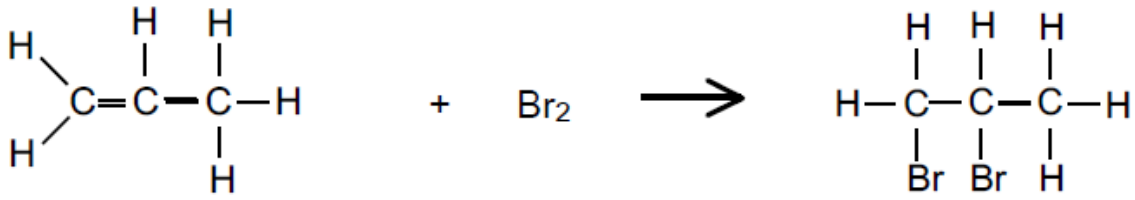
In an addition reaction two or more molecules combine to form one product. In this case the double carbon-to-carbon bond has been replaced by a single bond. The product is saturated.

When bromine solution is added to an unsaturated hydrocarbon the orange colour of the bromine will disappear and the bromine is said to have been decolourised (don't say goes clear - it was clear to begin with!). If bromine solution is added to a saturated substance there is no immediate colour change. This means that bromine solution is used to test if a molecule is saturated or not.

The Bromine Test

Bromine solution can be added to determine if a molecule is saturated or unsaturated. When bromine is added to an unsaturated substance such as hexene it will decolourise immediately. Unsaturated hydrocarbons will decolourise bromine solution and saturated hydrocarbons have no effect on bromine as the orange colour remains.

propene with bromine



orange

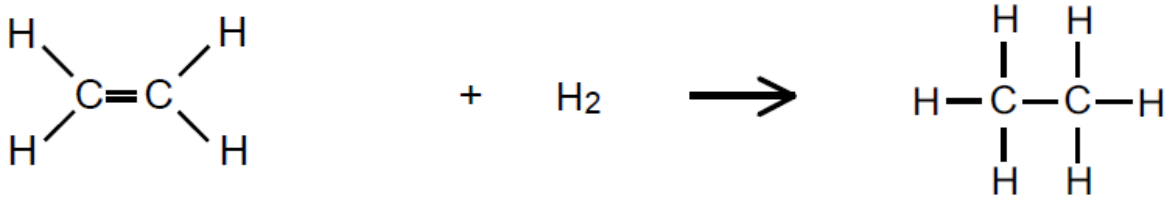
colourless

Hydrocarbon Reactions

Addition of Hydrogen (Hydrogenation)

You have seen that alkenes react with bromine solution since an addition reaction occurs. Similar reactions also occur between the alkenes and hydrogen. In a similar way the hydrogen molecules will add to the alkene molecule with the loss of the carbon-to-carbon double bond. Alkenes will therefore react with hydrogen to produce the corresponding alkane. The addition of hydrogen can be called **hydrogenation**.

Example: Ethene reacting with hydrogen to form ethane in an addition reaction.

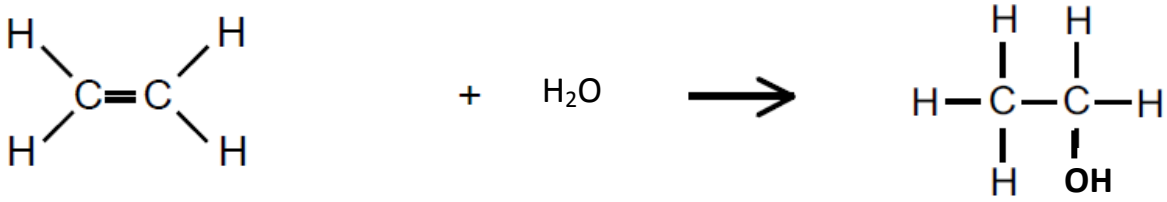


Alkenes will also react with chlorine in a similar way.

Addition of Water (Hydration)

Water will also react with alkene molecules causing the double bond to break. Water reacting with an alkene is also an example of an addition reaction but this is also called a hydration reaction. The alkene will react to form an alcohol molecule. Alcohols will be covered during Topics 2 and 3.

Example: Ethene reacting with water to form ethanol.



Ethanol (an alcohol)

Topic 1 Summary Statements

- ☐ A hydrocarbon is a compound made of hydrogen and carbon only.
- ☐ Alkanes, alkenes and cycloalkanes are each a subset of the set of hydrocarbons.
- ☐ An alkane can be identified from the -ane ending in the name.
- ☐ The alkanes are named as methane, ethane, propane, butane, pentane, hexane, heptane and octane.
- ☐ The general formula for the alkanes is C_nH_{2n+2}.
- ☐ A homologous series is a set of compounds with the same general formula, similar chemical properties and gradual changing physical properties.
- ☐ Alkanes, alkenes and cycloalkanes are each an example of a homologous series.
- ☐ Branched-chain alkanes can be named using a convention.
- ☐ An alkene has a name ending in –ene.
- ☐ All alkenes have at least one carbon to carbon double bond.
- ☐ The general formula for the alkenes is C_nH_{2n}.
- ☐ Cycloalkanes are a family of compounds where the carbon atoms are joined in a circle.
- ☐ The general formula for the cycloalkanes is C_nH_{2n+2}.
- ☐ Isomers are compounds with the same molecular formulae but different structural formulae.
- ☐ The alkanes and cycloalkanes are saturated hydrocarbons since they contain only single carbon-to-carbon bonds.
- ☐ The alkenes are unsaturated since they contain at least one carbon to carbon double covalent bond.
- ☐ It is possible to distinguish an unsaturated hydrocarbon from a saturated hydrocarbon using bromine solution. The bromine solution will be decolourised showing a molecule to be unsaturated.
- ☐ When an alkene reacts with hydrogen it will form the corresponding alkane.
- ☐ The reactions of an alkene with bromine, hydrogen (hydrogenation) and water (hydration) are examples of addition reactions.