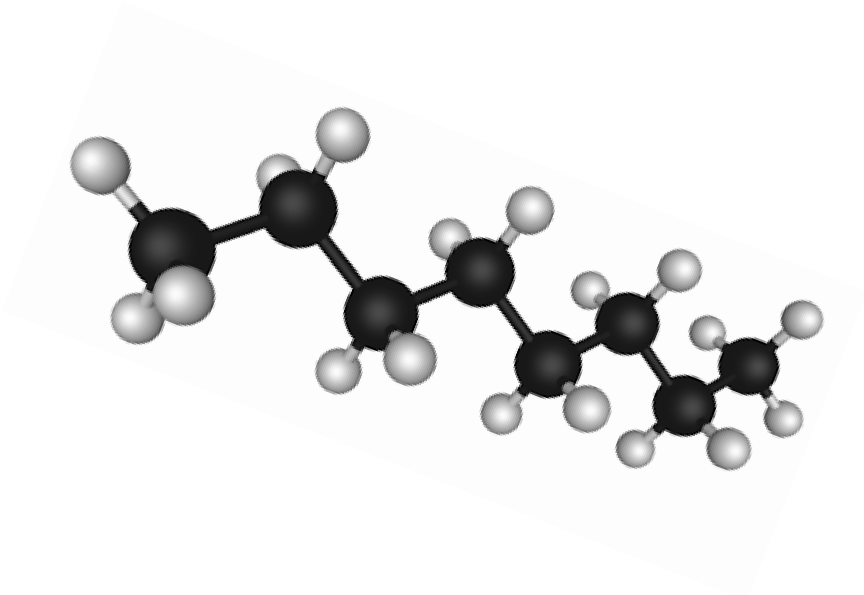
National 5 Chemistry

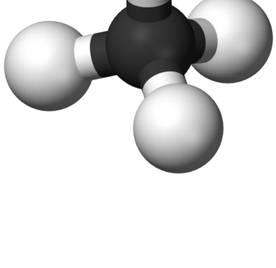
Unit 2 Nature's Chemistry

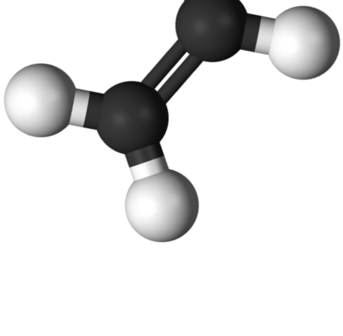
Summary Notes

Topic 1

Homologous Series







Learning Outcomes

Systematic carbon chemistry

- A homologous series is a family of compounds with the same general formula and similar chemical properties.
- Patterns are often seen in the physical properties of the members of a homologous series.
- The subsequent members of a homologous series show a general increase in their melting and boiling points. This pattern is attributed to increasing strength of the intermolecular forces as the molecular size increases. The type of intermolecular force does not need to be identified.
- Hydrocarbons are compounds containing only hydrogen and carbon atoms.
- Compounds containing only single carbon–carbon bonds are described as saturated.
- Compounds containing at least one carbon–carbon double bond are described as unsaturated.
- It is possible to distinguish an unsaturated compound from a saturated compound using bromine solution. Unsaturated compounds decolourise bromine solution quickly.
- The structure of any molecule can be drawn as a full or a shortened structural formula.
- Isomers:
    - are compounds with the same molecular formula but different structural formulae
    - may belong to different homologous series
    - usually have different physical properties
- Given a structural formula for a compound, an isomer can be drawn.
- Isomers can be drawn for a given molecular formula.

Alkanes

- Are a homologous series of saturated hydrocarbons
- Are commonly used as fuels
- Are insoluble in water
- Can be represented by the general formula C_nH_{2n+2}
- Straight-chain and branched alkanes can be systematically named from structural formulae containing no more than 8 carbons in the longest chain.
- Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain and branched alkanes, containing no more than 8 carbons in the longest chain.

Cycloalkanes

- Are a homologous series of saturated, cyclic hydrocarbons
- Are used as fuels and solvents
- Are insoluble in water
- Can be represented by the general formula C_nH_{2n}
- Cycloalkanes (C3–C8) can be systematically named from structural formulae. Branched cycloalkanes are not required.
- Molecular formulae can be written and structural formulae can be drawn from the systematic names of un-branched cycloalkanes.

Alkenes

- Are a homologous series of unsaturated hydrocarbons
- Are used to make polymers and alcohols
- Are insoluble in water
- Contain the C=C double bond functional group
- Can be represented by the general formula C_nH_{2n}
- Straight-chain and branched alkenes can be systematically named indicating the position of the double bond, from structural formulae containing no more than 8 carbon atoms in the longest chain.
- Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain and branched alkenes, containing no more than 8 carbons in the longest chain.
- Chemical equations can be written for the addition reactions of alkenes, using molecular or structural formulae.
- Alkenes undergo addition reactions:
  - with hydrogen forming alkanes, known as hydrogenation
  - with halogens forming dihaloalkanes
  - with water forming alcohols, known as hydration

Hydrocarbon Families

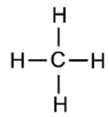
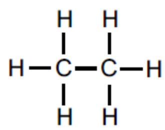
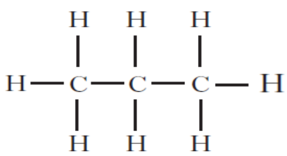
A **hydrocarbon** is a compound which contains **only** carbon and hydrogen.

A **homologous** series is a family of compounds with the same general formula and similar chemical properties. Within a homologous series, patterns in physical properties can be seen. For example, there is a general increase in melting and boiling point as the members in the homologous series get bigger. This pattern in melting and boiling point is related to the increasing strength of intermolecular force between the molecules. The larger the molecule, the stronger the intermolecular force.

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.

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

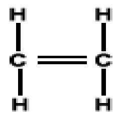
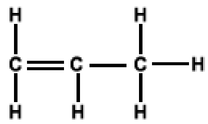
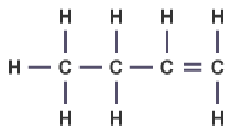
Name of Alkane	No of C atoms in molecule	Molecular Formula	Full Structural Formula	Shortened Structural Formula
methane	1	CH_4		CH_4
ethane	2	C_2H_6		CH_3CH_3
propane	3	C_3H_8		$CH_3CH_2CH_3$

The general formula for the alkanes is $\mathbf{C_nH_{2n+2}}$

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 since at least 2 carbons are needed to have a double carbon-to-carbon bond, the molecule methene does not exist.

Name of Alkane	No of C atoms in molecule	Molecular Formula	Full Structural Formula	Shortened Structural Formula
ethene	2	C_2H_4		$CH_2{=}CH_2$
propene	3	C_3H_6		$CH_2{=}CHCH_3$
butene	4	C_4H_8		$CH_3CH_2CH{=}CH_2$

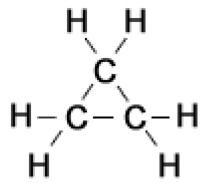
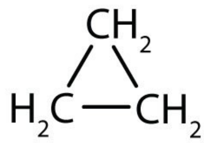
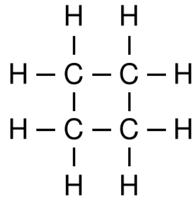
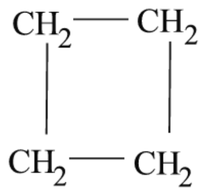
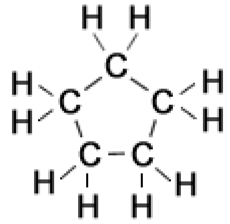
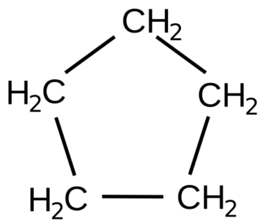
The general formula for the alkenes is $\mathbf{C_nH_{2n}}$

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.

Cycloalkanes are used as fuels and solvents. They are insoluble in water.

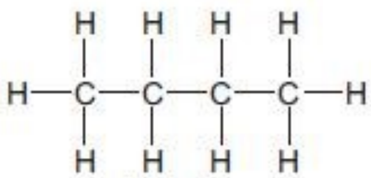
The general formula for the cycloalkanes is $\mathbf{C_nH_{2n}}$

Name of Cycloalkane	No of C atoms in molecule	Molecular Formula	Full Structural Formula	Shortened Structural Formula
cyclopropane	3	C_3H_6		
cyclobutane	4	C_4H_8		
cyclopentane	5	C_5H_{10}		

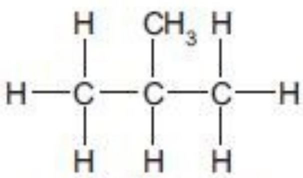
Isomers

Isomers are compounds with the same molecular formula but a different structural formula.

Example 1: butane and methyl propane



butane

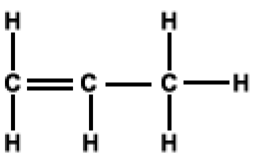


methylpropane

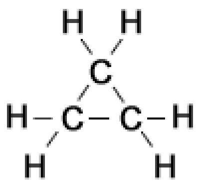
Example 2: but-1-ene and but-2-ene

but-1-ene	$CH_3-CH_2-CH=CH_2$
but-2-ene	$CH_3-CH=CH-CH_3$

Example 3: propene and cyclopropane



propene

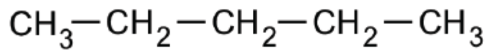


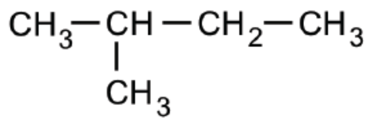
cyclopropane

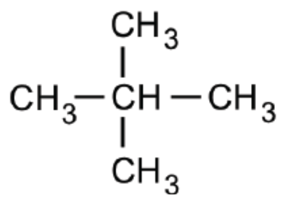
Naming Alkanes

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 rule.

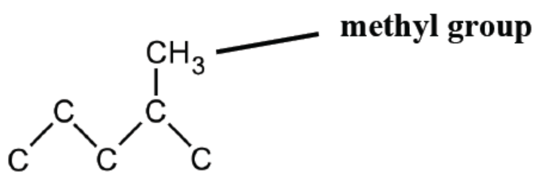
Consider the compound with molecular formula C_5H_{12}: there are several different molecules with this molecular formula. Below, A is a **straight-chain** molecule while B & C are **branched** chain molecules.

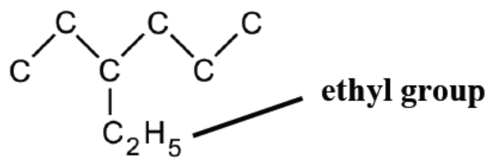
A 

B 

C 

Each molecule will 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:

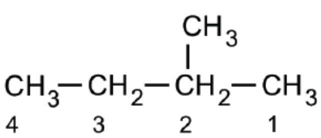
i) select the longest continuous chain of carbon atoms and name it after the appropriate alkane

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

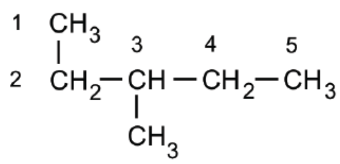
iii) name the branch(es) and indicate the position(s) of the branch(es) on the chain

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

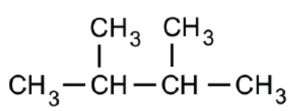
e.g.



2-methylbutane



3-methylpentane



2,3-dimethylbutane

** Remember you **cannot** have a branch on carbon one**

** Every branch present in the molecule must have a number associated with it**

Hydrocarbon Families

Naming Alkenes

For alkene molecules a number is used to indicate the position of the double carbon-to-carbon bond.

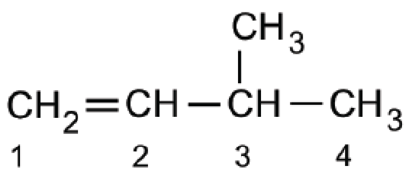
Alkenes, like alkanes, can also form branched chain molecules. Branched alkenes are named in a similar way to branched alkanes.

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 the end nearest 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:



When naming an alkene the double bond takes priority over any branches!

3-methylbut-1-ene

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.

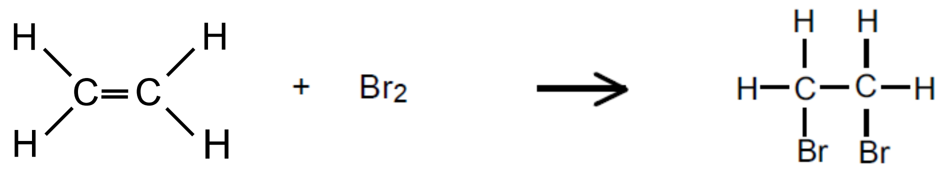
Uses of Hydrocarbons

Homologous Series	**Use**	**Solubility in water**
Alkanes	Fuels	Insoluble
Alkenes	Make polymers and alcohols	Insoluble
Cycloalkanes	Fuels and solvents	Insoluble

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.



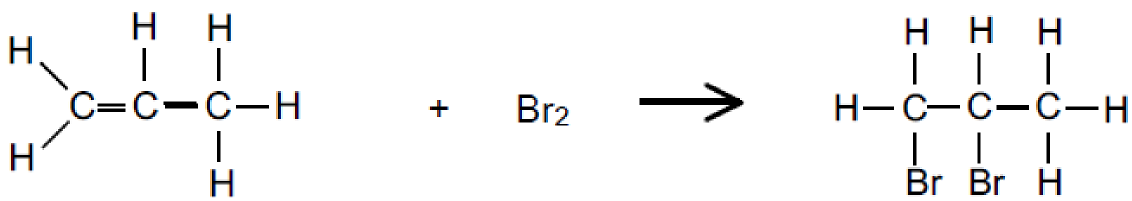
In an addition reaction two or more molecules combine to form one product. In this case the double carbon-to-carbon bond has been replaced by a single bond. The product is saturated.

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



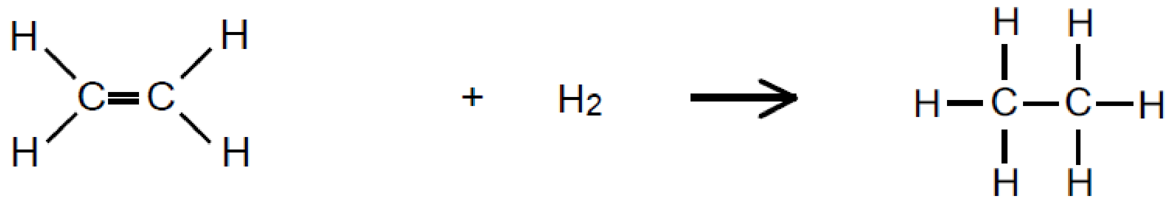
orange | colourless

While Bromine tests for unsaturation, other halogens eg. Cl_2 and F_2 can also undergo addition across double bonds to produced saturated dihaloalkanes.

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 saturated alkane. The addition of hydrogen can be called **hydrogenation**.

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

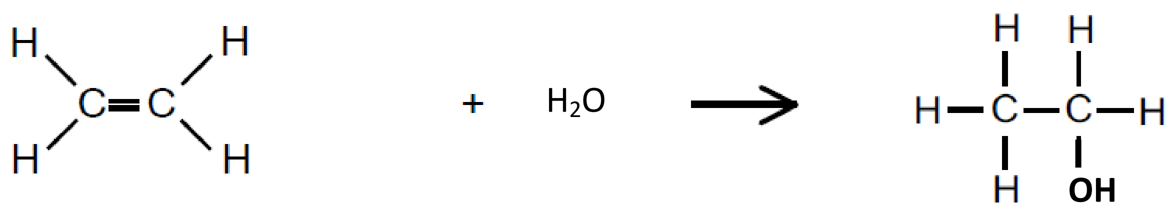


Alkenes will also react with chlorine in a similar way.

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 the corresponding alcohol molecule.

Example: Ethene reacting with water to form ethanol.



Ethanol (an alcohol)

Topic Questions

Exercise 1

1. What is the general formula for the alkanes?
2. What is the molecular formula for the alkane with 10 carbon atoms?
3. What is the molecular formula for the alkane with 20 hydrogen atoms?
4. What is the molecular formula for the 23rd member of the alkane family?
5. Give the correct molecular formula for each of the following:

   a) $C_{15}H\_$ b) C_H_{34} c) $C_{50}H\_$ d) C_H_{54} e) C_H_{56}

6. Which of the following molecular formulae could represent an alkane molecule?

   i) C_2H_4 ii) $C_{18}H_{38}$ iii) $C_{10}H_{20}$ iv) $C_{15}H_{28}$ v) C_7H_{16}

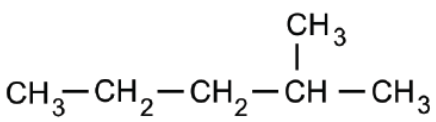
Exercise 2

1. Explain why the alkane family is an example of a hydrocarbon family.
2. What is meant by the term homologous series?
3. What is meant by a general formula?
4. What is meant by the chemical properties of a substance?
5. Give three examples of physical properties.

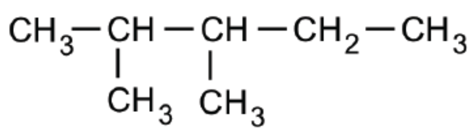
Exercise 3

1. Give the systematic name for each of the following molecules.

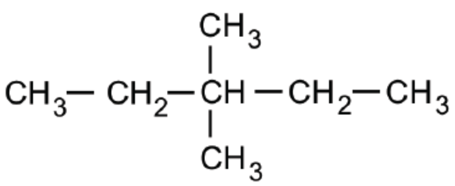
a)



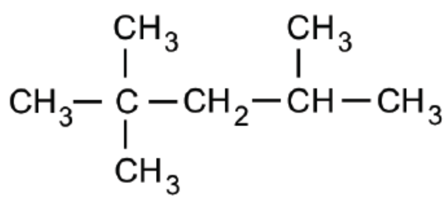
b)



c)



d)

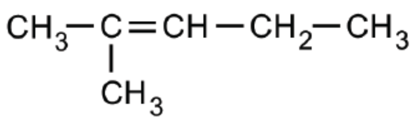


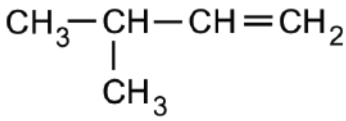
2. Draw full and then shortened structural formula for each of the following compounds.

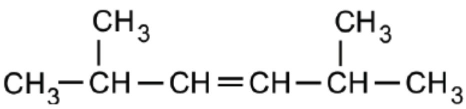
   a) 2-methylheptane b) 2,2,3-trimethylhexane c) 3,3-diethylhexane
   d) 2,4-dimethylhexane e) 3-ethyl-2-methylheptane

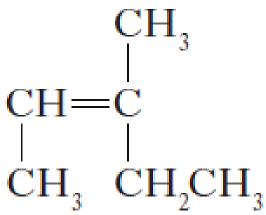
Exercise 4

1. Give the systematic name for each of the following molecules.

a) 

b) 

c) 

d) 

2. Draw the full and shortened structural formulae for each of the following molecules.

   a) 4-methylpent-2-ene

   b) 2,4-dimethylpent-1-ene

   c) 2,4,4-trimethylhex-1-ene

   d) 3-methylhex-3-ene

   e) 3,4-diethylhept-1-ene

3. How are the carbon atoms arranged in cycloalkane molecules?

4. Determine the general formula for the cycloalkanes.

5. Explain why the cycloalkanes are an example of a homologous series.

6. State which of the following molecular formulae could represent a cycloalkane molecule.

   i) $C_{10}H_{20}$ ii) C_5H_{12} iii) $C_{12}H_{24}$ iv) C_2H_4 v) C_6H_{10}

Exercise 5

1. Give the general formula for the following hydrocarbon families:

   i) Alkanes ii) Alkenes iii) Cycloakanes

2. Explain what is meant by the term

   a) saturated hydrocarbon

   b) unsaturated hydrocarbon

3. a) Explain what is meant by a homologous series.

b) In each of the following lists of hydrocarbons identify one that is in a different homologous series from the others.

i)	ethane	butene	methane	octane
ii)	C_3H_8	CH_4	C_7H_{14}	$C_{12}H_{26}$
iii)	C_2H_4	C_6H_{12}	CH_4	C_4H_8

4. State the molecular formula for each of the following.

a) The saturated straight-chain hydrocarbon with 12 carbon atoms per molecule.

b) The unsaturated straight-chain hydrocarbon with 10 carbon atoms per molecule.

c) The saturated cyclic hydrocarbon with 7 carbon atoms per molecule.

5. Explain what is meant by the term isomer.

6. (a) Draw the full structural formula for hexane.

(b) Draw the full structural formulae and name two other possible isomers of hexane.

7. (a) Draw the structural formula for cyclopentane.

(b) Draw the full structural formulae and name two other possible isomers of cyclopentane.

8. Unsaturated compounds are found in white spirit. Describe how you would test white spirit to show that it contains unsaturated molecules.

9. $C_2H_4 + Br_2 \longrightarrow X$

a) Draw the full structural formula for substance X.

b) What name is given to this type of reaction?

c) Name the product of the reaction of C_2H_4 with hydrogen.

Exercise 6

1. Which of the following could be the molecular formula for a cycloalkane?

   A C_7H_{16} B C_7H_{14} C C_7H_{12} D C_7H_{10}

2. A student was testing some hydrocarbons for unsaturation. Results from the experiment are shown below.

Hydrocarbon	Molecular formula	Observation with bromine solution	Saturated or unsaturated
A	C_6H_{14}	no change	
B	C_6H_{12}		unsaturated
C	C_6H_{12}		saturated
D	C_6H_{10}	bromine decolourises	

   a) Complete the table.

   b) Suggest a possible name for hydrocarbon **B**.

3. Draw the full structural formula for each of the following.

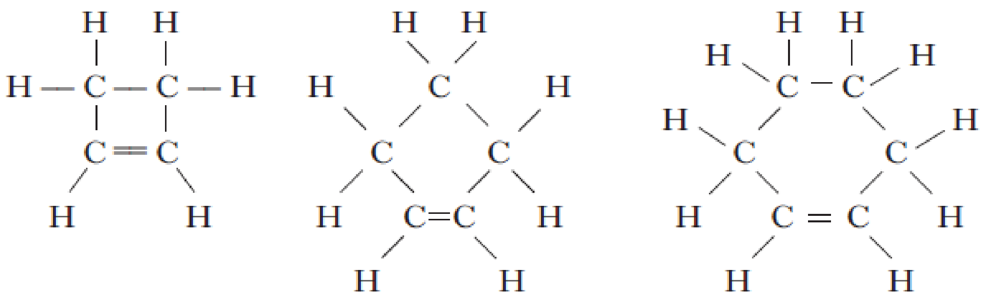
   a) 2-methylpentane b) 3-methylpent-1-ene

   c) 2,5-dimethylheptane d) 2,4-dimethylhex-3-ene

4. Which of the following compounds fits the general formula, C_nH_{2n}, and will rapidly decolourise bromine solution?

   A Cyclopentane B Pentane C Propene D Cyclopropane

5. Three members of a hydrocarbon family are shown below.



   a) State the general formula for this hydrocarbon family.

   b) Draw the full structural formula for the first (smallest) member of this family.

Exercise 7

1. Draw the full structural formula for the following molecules

    a) Heptane

    b) Methane

    c) Pent-2-ene

    d) But-1-ene

    e) Cyclopentane

    f) Methylpropene

    g) 3,4 – dimethylheptane

2. Draw the shortened structural formula for the following molecules:

    a) Ethane

    b) Hept-2-ene

    c) Cyclobutane

    d) Methylcyclopentane

    e) 3,4-dimethylheptane

    f) 2,2-dimethylbutane

3. Decide whether or not the following pairs are isomers:

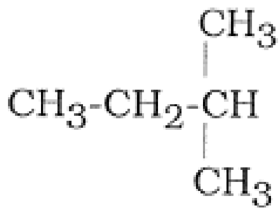
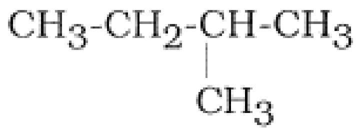
    1. $\mathrm{CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3}$ and $\mathrm{CH_3\text{-}CH_2\text{-}CH_3}$

    2. $\mathrm{CH_3\text{-}CH_3}$ and $\mathrm{CH_2{=}CH_2}$

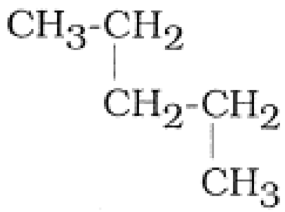
    3. $\mathrm{CH_3\text{-}\underset{\displaystyle CH_3}{\underset{|}{C}}H\text{-}CH_3}$ and $\mathrm{CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3}$

    4. $\mathrm{CH_3\text{-}CH_2\text{-}\underset{\displaystyle CH_3}{\underset{|}{C}}H\text{-}CH_3}$ and $\mathrm{CH_3\text{-}\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}\text{-}CH_3}$

    5. $\mathrm{CH_3\text{-}\overset{\displaystyle CH_3}{\overset{|}{C}}H\text{-}CH_2\text{-}CH_3}$ and $\mathrm{CH_3\text{-}CH_2\text{-}\underset{\displaystyle CH_3}{\underset{|}{C}}H\text{-}CH_3}$

6.  and 

7. $CH_3\text{-}CH{=}CH\text{-}CH_3$ and $CH_3\text{-}CH{=}CH_2$

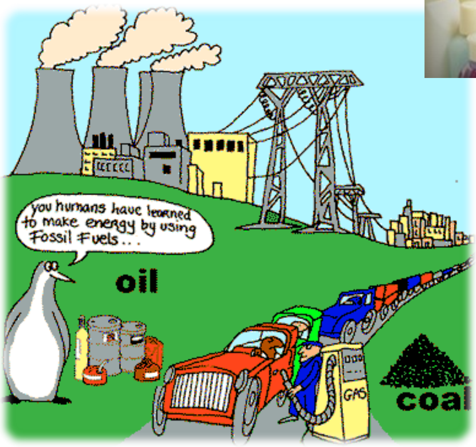
8.  and $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$

9. $CH_2{=}CH\text{-}CH_2\text{-}CH_3$ and $CH_3\text{-}CH_2\text{-}CH{=}CH_2$

Topic 2

Everyday Consumer Products

Energy from Fuels



Learning Outcomes

Alcohols

- Alcohols are used as fuels as they are highly flammable and burn with very clean flames.
- Alcohols are often used as solvents.
- Methanol, ethanol and propanol are miscible with water, thereafter the solubility decreases as size increases.
- As alcohols increase in size their melting and boiling points increase due to the increasing strength of the intermolecular forces. The type of intermolecular force does not need to be identified.
- An alcohol is a molecule containing a hydroxyl functional group, –OH group.
- Saturated, straight-chain alcohols can be represented by the general formula $C_nH_{2n+1}OH$.
- Straight-chain alcohols can be systematically named indicating the position of the hydroxyl group from structural formulae containing no more than 8 carbon atoms.
- Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain alcohols, containing no more than 8 carbons.

Carboxylic Acids

- Carboxylic acids are used in the preparation of preservatives, soaps and medicines.
- Vinegar is a solution of ethanoic acid, with molecular formula CH_3COOH.
- Vinegar is used in household cleaning products as it is a non-toxic acid so can be used safely in household situations.
- Methanoic, ethanoic, propanoic and butanoic acid are miscible in water, thereafter the solubility decreases as size increases.
- As carboxylic acids increase in size their melting and boiling points increase due to the increasing strength of the intermolecular forces. The type of intermolecular force does not need to be identified.
- Carboxylic acids can be identified by the carboxyl functional group, –COOH.
- Carboxylic acids can be represented by the general formula $C_nH_{2n+1}COOH$.
- Straight-chain carboxylic acids can be systematically named from structural formulae containing no more than 8 carbons.
- Molecular formulae can be written and structural formulae drawn, from the systematic names of straight-chain carboxylic acids, containing no more than 8 carbons.
- Solutions of carboxylic acids have a pH less than 7 and like other acids, can react with metals, metal oxides, hydroxides and carbonates forming salts.
- Salts formed from straight chain carboxylic acids containing no more than 8 carbons, can be named.

Energy from fuels

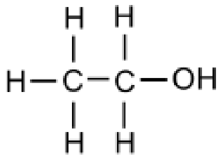
- A reaction or process that releases heat energy is described as exothermic.
- A reaction or process that takes in heat energy is described as endothermic.
- In combustion, a substance reacts with oxygen releasing energy.
- Hydrocarbons and alcohols burn in a plentiful supply of oxygen to produce carbon dioxide and water.
- Equations can be written for the complete combustion of hydrocarbons and alcohols.
- Fuels burn releasing different quantities of energy.
- The quantity of heat energy released can be determined experimentally and calculated using, $E_h = cm\Delta T$.
- The quantities E_h, c, m or ΔT can be calculated, in the correct units, given relevant data.
- Calculations can involve heating substances other than water. It is not necessary to calculate the enthalpy per mole of substance burned.

Alcohols

The Alcohols

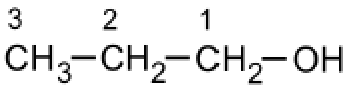
Alcoholic drinks have been known of for thousands of years. Many people use alcoholic drinks to celebrate social occasions whilst other people do not drink alcoholic beverages. There are many different alcohols but the alcohol present in alcoholic drinks is ethanol.

All alcohols contain a hydroxyl functional group (OH). The atoms in the hydroxyl group are attached by a covalent bond to form part of the molecule.

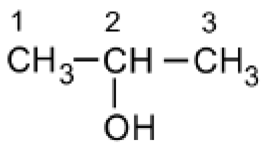


ethanol

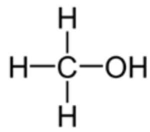
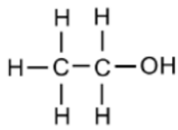
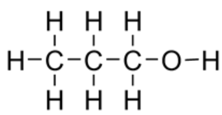
Alcohols are named in a similar way to the alkanes. The general formula for the alcohols is $C_nH_{2n+1}OH$.



propan-1-ol



propan-2-ol

Name	Number of Carbon atoms	Molecular Formula	Shortened Structural Formula	Full Structural Formula
Methanol	1	CH_3OH	CH_3OH	
Ethanol	2	C_2H_5OH	CH_3CH_2OH	
Propanol	3	C_3H_7OH	$CH_3CH_2CH_2OH$	

Alcohols

Systematic Naming

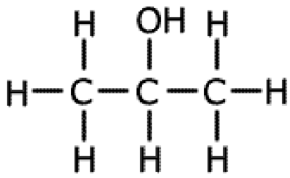
Naming alcohols follows the same rules as naming alkanes and alkenes:

i) Select the longest continuous chain of carbon atoms and name it using the appropriate prefix (meth = 1, eth = 2, etc).

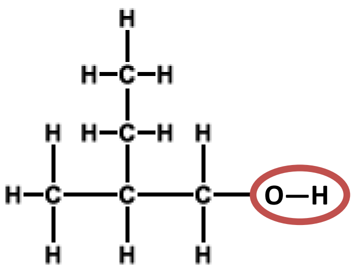
ii) Number the carbon atoms from the end nearest the hydroxyl group (-OH) and indicate the position of the hydroxyl group **within** the alcohol name (propan-1-ol).

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

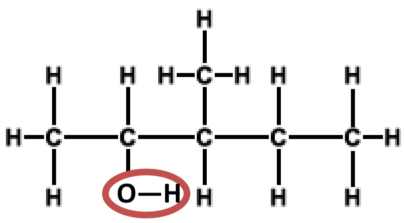
Eg.



Propan-2-ol



2-methyl butan-1-ol



3-methyl pentan-2-ol

Properties of Alcohols

Melting/Boiling Points

The melting and boiling points of alcohols increase with increasing length of carbon chain. Larger alcohol molecules have stronger forces between them and therefore increased melting and boiling points.

Flammability

All alcohol molecules will burn easily with a clean flame. Flammability decreases with increasing length of alcohol molecule. When an alcohol molecule burns in a plentiful supply of air carbon dioxide and water are produced (combustion reaction).

Solubility/Miscibility

Alcohols are soluble in water and therefore dissolve to form solutions. The solubility decreases with increasing size of molecule. Methanol, ethanol and propanol are miscible (will mix) with water, thereafter the miscibility decreases as size of the alcohol molecule increases.

Uses of Alcohols

Ethanol is the alcohol found in alcoholic drinks, alcohols have a variety of other uses in everyday life.

Alcohols as Solvents

Short chain alcohols, such as methanol, ethanol and propanol are able to dissolve a variety of compounds and therefore are used as solvents. They are also used in cleaning products since they have the ability to dissolve a variety of compounds and evaporate easily. For example; screen wipes, baby wipes, alcohol hand gels and disinfectant wipes.

Alcohols as Fuels

Alcohols are highly flammable. They react with oxygen (combust) to produce carbon dioxide and water.

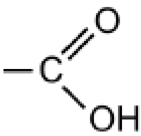
Example: Methanol $CH_3OH + O_2 \longrightarrow CO_2 + H_2O$

Alcohols burn with a very clean flame. When they burn, they release a significant amount of energy, this means they are able to be used as fuels. **A fuel is substance which burns to give out energy.**

Ethanol can be produced by the fermentation of sugar cane. This means it can be regarded as a renewable source of energy, as the sugar cane can easily be regrown. The ethanol produced can be used as a fuel, or mixed with petrol or diesel to produce a fuel blend.

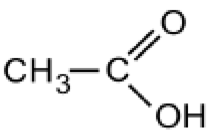
The Carboxylic Acids

The carboxylic acids are another example of a homologous series. All carboxylic acids have a **name which ends in "anoic acid"** and contain the **carboxyl** group at the end of the molecule:



Carboxyl Group

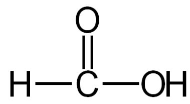
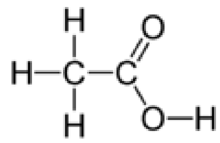
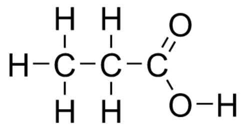
The carboxylic acids take a similar name as the other families we have met so far where a **prefix indicates the number of carbon atoms**. The first member of this homologous series is called methanoic acid, the second member is called ethanoic acid. In fact vinegar is a solution which contains ethanoic acid and this is what gives vinegar a sour taste.



Ethanoic Acid

The general formula for the carboxylic acids is $C_nH_{2n+1}COOH$.

Carboxylic Acids

Name	Number of Carbon atoms	Molecular Formula	Shortened Structural Formula	Full Structural Formula
Methanoic Acid	1	HCOOH	HCOOH	
Ethanoic Acid	2	CH_3COOH	CH_3COOH	
Propanoic Acid	3	C_2H_5COOH	CH_3CH_2COOH	

Properties of Carboxylic Acids

Uses

Carboxylic acids are used in the preparation of preservatives, soaps and medicines.

Melting/Boiling Point

As carboxylic acids increase in molecular size their melting and boiling points increase due to the increasing strength of the intermolecular forces (forces between the molecules).

Solubility/Miscibility

Small chain carboxylic acids are soluble in water. Methanoic acid, ethanoic acid, propanoic acid and butanoic acid are miscible (will mix) with water, thereafter the solubility decreases as size of the molecule increases.

Vinegar

Vinegar is a solution of ethanoic acid, with molecular formula CH_3COOH.

Vinegar is used in household cleaning products as it is a non-toxic acid so can be used safely in household situations. Cleaning chemicals which contain vinegar (ethanoic acid) do so, as the vinegar reacts with metal carbonates to produce soluble salts which are washed away easily.

Neutralisation with Carboxylic Acids

As seen previously (Acids and Alkalis, Unit 1) neutralisation reactions occur between acids and bases to produce a salt and water. As carboxylic acids are weak acids, they too can take part in neutralisation reactions

Carboxylic Acid + Base $\longrightarrow$ Salt + Water

Solutions of carboxylic acids can react with metals, metal oxides, metal hydroxides and metal carbonates forming carboxylate salts.

Salt Names

The name of the salt produced in a neutralisation reaction comes from a combination of the base used as well as the acid. The **start of the salt name comes from the metal present in the base** (as seen in unit 1). The ending of the salt name comes from the acid used. Carboxylic acids produce salts which end as follows:

Carboxylic Acid	**End of salt name**
Methanoic acid	Methanoate
Ethanoic acid	Ethanoate
Propanoic acid	Propanoate
Butanoic acid	Butanoate
Pentanoic acid	Pentanoate
Hexanoic acid	Hexanoate
Heptanoic acid	Heptanoate
Octanoic acid	Octanoate

Examples

Methanoic acid + Sodium Hydroxide $\longrightarrow$ Sodium Methanoate + Water

Butanoic acid + Lithium Oxide $\longrightarrow$ Lithium butanoate + Water

Propanoic acid + Calcium **Carbonate** $\longrightarrow$ Calcium Propanoate + Water + **Carbon dioxide**

Fuels

A Source of Energy

A **fuel** is a substance that burns to release energy. Much of our energy comes from burning fuels, e.g. wood was one of the first fuels used by humans. The **burning** of a fuel is a chemical reaction in which the fuel reacts with oxygen to make new substances. **Combustion** is another word for burning in oxygen to produce energy.

An exothermic reaction is one in which energy is released.

An endothermic reaction is one which energy is taken in.

Complete combustion involves the burning of a substance in a plentiful supply of oxygen to produce carbon dioxide and water. Both hydrocarbons and alcohols readily combust and can be written in the following combustion equations.:

Hydrocarbon + Oxygen $\longrightarrow$ Carbon dioxide + Water

Alcohol + Oxygen $\longrightarrow$ Carbon dioxide + Water

Combustion Equations

Example 1

Combustion of Butane : $C_4H_{10} + \mathbf{6.5}O_2 \longrightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$

Example 2

Combustion of Butanol : $C_4H_9OH + \mathbf{6}O_2 \longrightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$

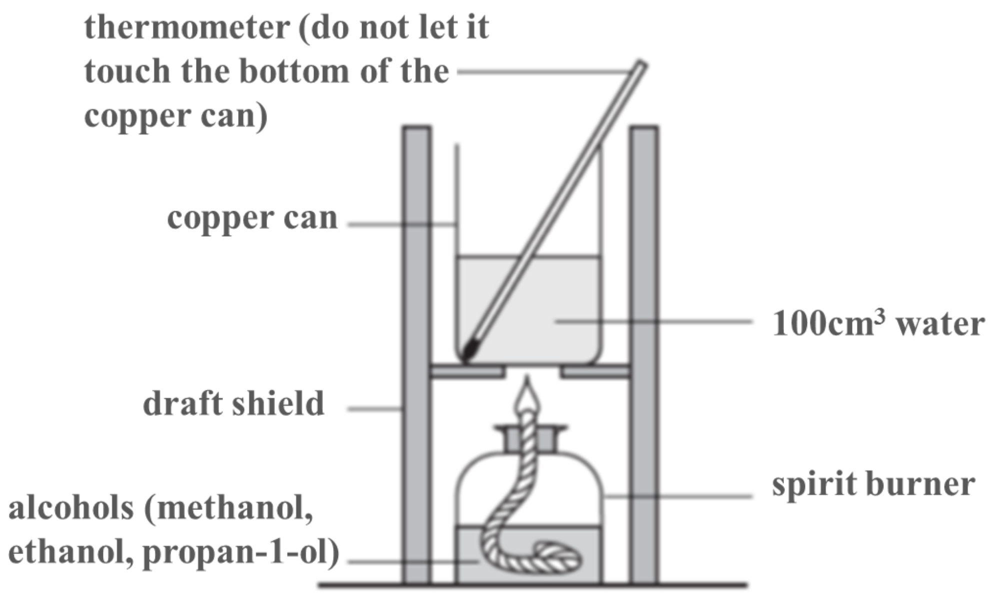
Example 3

Combustion of Propene

Example 4

Combustion of Ethanol

Burning Alcohols Experiment



Alcohols are examples of fuels, the above experiment can be carried out in order to calculate how much energy is produced when the alcohol (fuel) is burned.

In order to complete the calculation, you must use the following equation (found in the data book) :

$$\boxed{E_h = cm\Delta T}$$

Where E_h = Energy gained by the solution in kJ

c = Specific heat capacity in kJ kg^{-1} ^{o}C^{-1}

m = Mass of solution being heated (1 litre = 1 kg)

ΔT = Change in temperature of solution (^{o}C)

so *Heat energy = specific heat capacity x mass of liquid x temperature change*

Example: Volume of water = 200 cm^3 so m = 0·2 kg

ΔT = 20°C

Therefore:

$E_h = cm\Delta T$

E_h = 4·18 x 0·2 x 20 = <u>16·7 kJ</u>

In this example **c** is related to the specific heat capacity of **water** and is a constant found in the data book (p.3). If you have any other solution—you will need to calculate c by rearranging the equation.

Rearranging $E_h = cm\Delta T$

As with all equations in National 5 chemistry, you must have the skills to rearrange the equation in order to calculate the unknown.

$$c = \frac{E_h}{m\Delta T} \qquad m = \frac{E_h}{c\Delta T} \qquad \Delta T = \frac{E_h}{cm}$$

Example 1

Calculate the temperature change when a solution of sodium chloride was heated by burning methanol.

Specific heat capacity of methanol	2.545 kJ kg^{-1} ^{o}C^{-1}
Volume of sodium chloride	200cm^3
Heat energy produced	9.671 kJ

$$\Delta T = \frac{E_h}{cm}$$

$$= \frac{9.671}{2.545 \times 0.2}$$

$$= 19^{o}C$$

Example 2

Calculate the specific heat capacity of lithium chloride solution if 100g was heated by 31^{o}C. The heat energy produced was calculated to be 18.8 kJ.

$$c = \frac{E_h}{m\Delta T}$$

$$= \frac{18.8}{0.1 \times 31}$$

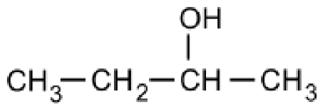
$$= 6.06 \text{ kJ kg}^{-1}\,^{o}C^{-1}$$

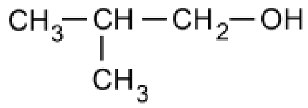
Topic Questions

Exercise 1

1. What is the general formula for the alcohol family.

2. Give the systematic name for each of the following alcohols.

a) 

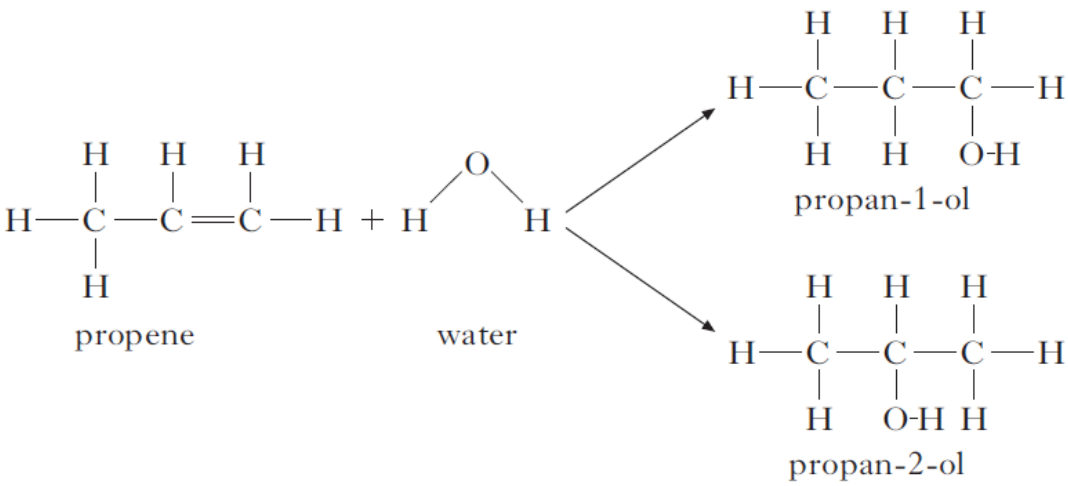
b) 

3. Draw the full structural formula for each of the following alcohols

a) butan-1-ol	b) hexan-3-ol
c) 3-methylpentan-1-ol	d) 3,3-dimethylbutan-2-ol
e) heptan-3-ol	f) 2,2-dimethylpropan-1-ol
g) propan-2-ol	h) 2-methylpentan-2-ol

Exercise 2

1. Ethanol is the alcohol found in alcoholic drinks. It can be produced in a variety of ways. In industry, alcohols can be produced from alkenes as shown in the example below.



a) Name this type of chemical reaction.

b) What term is used to describe a pair of alcohols like propan-1-ol and propan-2-ol?

c) Propan-1-ol and propan-2-ol have different boiling points. Name the process which can be used to separate a mixture of different substances with different boiling points.

2. a) Using the data booklet copy and complete the following table.

Alcohol	Number of carbon atoms per molecule	Boiling point (°C)
methanol		
ethanol		
propan-1-ol		
butan-1-ol		

b) Describe the relationship between the number of carbon atoms and the boiling point.

c) Predict the boiling point for pentan-1-ol which has 5 carbon atoms per molecule.

d) Explain the relationship between the size of the molecules and the boiling point in terms of the forces between molecules.

3. a) Alcohols like ethanol will burn easily. What term is used to describe burning?

b) Alcohols contain carbon, hydrogen and oxygen. Name two products which will be formed when an alcohol burns completely.

c) The flammability of the alcohols changes with increasing carbon chain length. Suggest if the flammability increases or decreases with increasing size of alcohol molecule.

4. a) Methanol and ethanol will dissolve easily in water. What term is used to describe a substance which can dissolve?

b) As the carbon chain length increases the solubility of the alcohols changes. Suggest if the solubility increases or decreases with increasing size of alcohol molecule.

Exercise 3

1. Which carboxylic acid is found in vinegar?

2. Ethanoic acid will react with potassium carbonate.

a) Write a word equation for this reaction.

b) If the chemical formula for potassium ethanoate is CH_3COOK, write a balanced equation for this reaction.

3. Draw the full structural formula for the following carboxylic acids.

a) butanoic acid

b) 3-methylpentanoic acid

c) 2-methylhexanoic acid

d) octanoic acid

e) 2-methylpropanoic acid

f) methanoic acid

4. Write out a balanced chemical equation for the following neutralisation reactions

a) ethanoic acid + lithium hydroxide $\longrightarrow$ lithium ethanoate + water

b) methanoic acid + sodium hydroxide $\longrightarrow$ sodium methanoate + water

5. For each of the following calculate the heat released by the burning of the fuel.

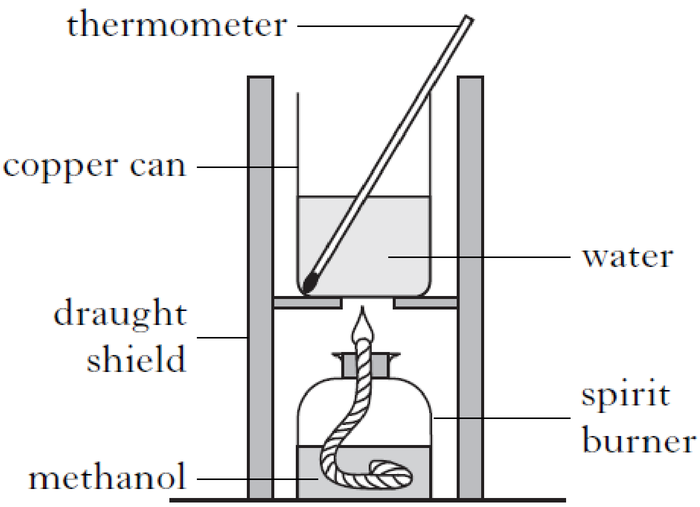
a) The temperature of 50 cm^3 is increased by 10°C.

b) The temperature of 100 cm^3 is increased by 33·5°C.

c) The temperature of 250 cm^3 is increased from 20·6°C to 32·1°C.

d) The temperature of 1·5 litres is increased from 15·2°C to 21·1°C.

6. A student used the simple laboratory apparatus shown to determine the energy released when 1 gram of methanol burned.



a) Draw the structural formula for methanol.

b) What measurements are needed to calculate the energy released by the burning methanol?

c) The student found that burning 0·370 g of methanol produces 3·86 kJ of energy.

i) Use this result to calculate the heat released per gram of methanol burned.

ii) Use this result to calculate the heat released per mole of methanol burned. (GFM = 32)

Exercise 4

1. Draw the full structural formula for each of the following alcohols.

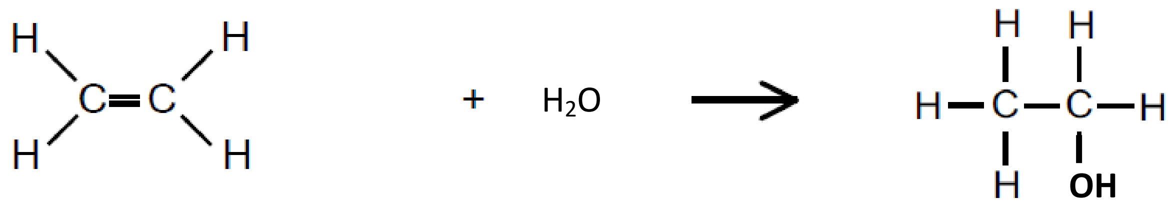
   a) pentan-2-ol b) hexan-3-ol

   c) 2-methylpentan-1-ol d) 2-methylpropan-2-ol

2. Draw the full structural formula for 3 alcohols which have the formula C_4H_9OH. Give the names of each of the molecules.

3. Alcohols can be formed by carrying out a hydration reaction of an alkene.

   For example, ethanol can be formed by reacting ethene with water.



   a) What other name can be given to this type of reaction.

   b) Draw the full structural formulae for the two possible isomers that can be produced when propene undergoes a similar reaction with water.

4. Ethanol for alcohol drinks can be made by the fermentation of glucose found in plants. The table below shows the relationship between the percentage of ethanol and the density of alcoholic drinks.

Percentage of ethanol (%)	40	50	60	70	80
Density of alcoholic drink (g/cm^3)	0·928	0·907	0·886	0·865	0·844

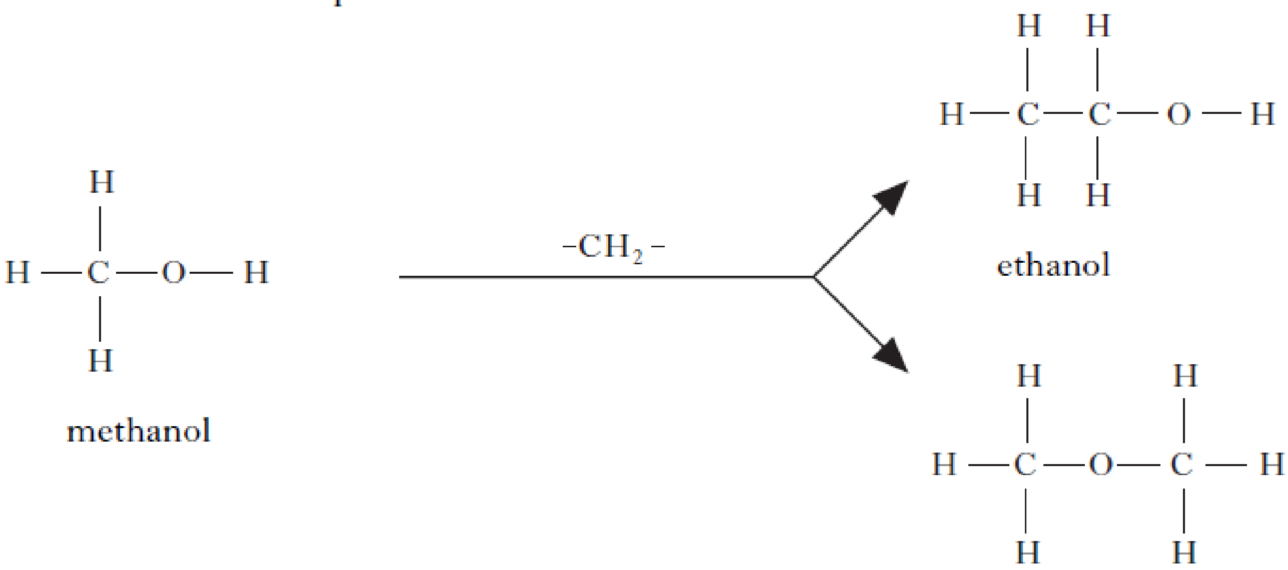
   a) Write a general statement describing how the percentage of ethanol affects the density of the alcoholic drink.

   b) The density of a particular brand of alcoholic drink is 0·970 g/cm^3

   Predict the percentage of ethanol in this alcoholic drink.

5. Chemists have discovered a way to insert a $-CH_2-$ group into any bond which includes an atom of hydrogen.

When a $-CH_2-$ group is inserted into a methanol molecule the following reaction takes place.

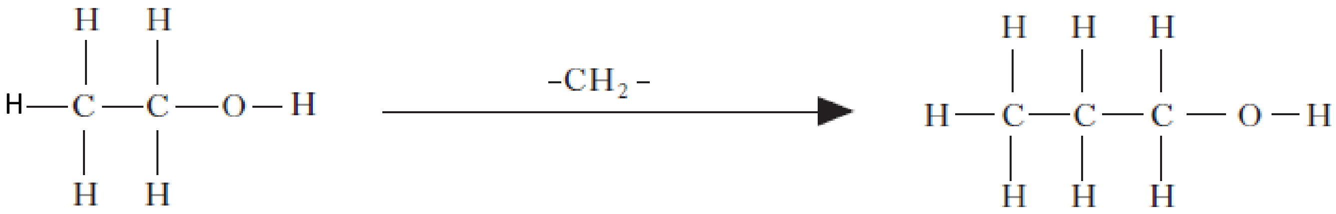


methanol

ethanol

This reaction can be repeated using ethanol.

One of the products for this reaction is shown.



ethanol

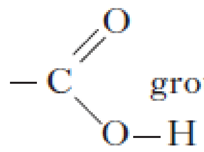
molecule **X**

a) Suggest a name for molecule **X.**

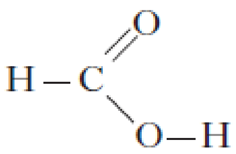
b) Draw a structural formula for another molecule which could be formed in this reaction.

6. Draw the full structural formula for the following carbohydrate molecules

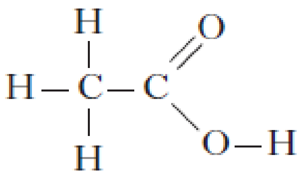
a)	ethanol	b)	hexan-2-ol
c)	2-methylbutan-2-ol	d)	pentanoic acid
e)	3-methylheptanoic acid	f)	propanoic acid
g)	butan-2-ol	h)	methanol
i)	ethanoic acid	j)	2,3-dimethylbutanoic acid

7. Alkanoic acids are a family of compounds which contain the  group.

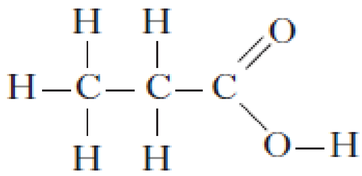
The **full** structural formulae for the first three members are shown.



methanoic acid



ethanoic acid



propanoic acid

(*a*) Draw the **full** structural formula for the alkanoic acid containing 4 carbon atoms.

(*b*) The table gives information on some alkanoic acids.

Acid	*Boiling point/ °C*
methanoic acid	101
ethanoic acid	118
propanoic acid	141
butanoic acid	164

(i) Using this information, make a general statement linking the boiling point to the number of carbon atoms.

____

____

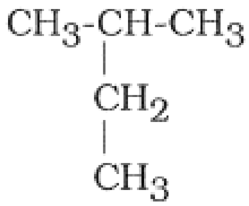
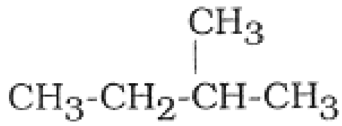
____

(ii) Predict the boiling point of pentanoic acid.

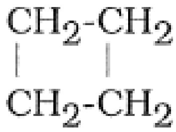
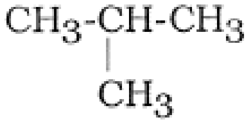
____________ °C

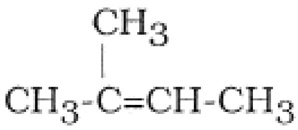
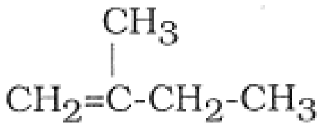
Exercise 5

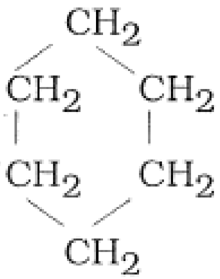
1. Decide whether the following pairs of molecule are isomers or not

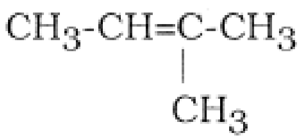
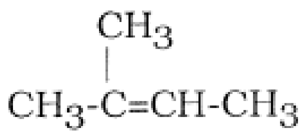
a)  and 

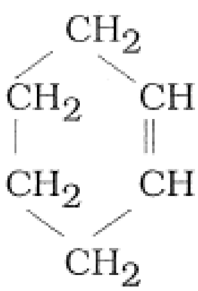
b) $CH_3\text{-}CH{=}CH\text{-}CH_3$ and $CH_2{=}CH\text{-}CH_2\text{-}CH_3$

c)  and 

d)  and 

e)  and $CH_2{=}CH\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$

f)  and 

g)  and $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}C{\equiv}CH$

Exercise 6

1. The data below was collected when the energy released, by burning an alcohol, was used to heat sodium chloride solution

Energy releases (kJ) = 13.3

Initial temperature of sodium chloride solution (^oC) = 15

Final temperature of sodium chloride solution (^oC) = 49

Mass of sodium chloride solution heated (g) = 100

Calculate the specific heat capacity, in kJ $kg^{-1}\,^oC^{-1}$, of the sodium chloride solution.

2. Calculate the specific heat capacity of lithium sulfate solution if 100g was heated by burning ethanol. The energy produced was 15.5kJ and the temperature of the lithium sulfate rose from 10^oC - 33^oC.

3. Calculate the specific heat capacity of magnesium chloride solution (200g) if, when heated by burning alcohol, the temperature rose by 22^oC. The energy produced was calculated to be 10.2 kJ.

4. Calculate the change in temperature when 100g of water was heated by burning methanol. The energy calculated from this reaction was 13.3 kJ.

5. Calculate the mass of water burned is 15.0 kJ of energy was released when the temperature rose from 21^oC – 31^oC.

Exercise 7

1. Name the salts made during the following neutralisation reactions:

a) methanoic acid + sodium hydroxide

b) pentanoic acid + lithium oxide

c) ethanoic acid + magnesium hydroxide

d) butanoic acid + sodium hydroxide

e) methanoic acid + potassium hydroxide

f) octanoic acid + lithium hydroxide

g) propanoic acid + calcium oxide

h) heptanoic acid + magnesium oxide

i) ethanoic aicd + sodium hydroxide

j) methanoic acid + lithium carbonate

k) pentanoic acid + calcium carbonate

l) hexanoic acid + magnesium carbonate