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GCSE Chemistry

AQA Topic – Organic Chemistry

Overview
Organic Chemistry

Carbon compounds as fuels and feedstock

- Crude oil, hydrocarbons and alkanes
- Fractional distillation and petrochemicals
- Properties of hydrocarbons
- Cracking and alkenes

Reactions of alkenes and alcohols (Chemistry only)

- Structure and formulae of alkenes
- Reactions of alkenes
- Alcohols
- Carboxylic acids

Synthetic and naturally occurring polymers (Chemistry only)

- Addition polymerisation
- Condensation polymerisation (HT only)
- Amino acids (HT only)
- DNA and other naturally occurring polymers

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Carbon compounds as fuels and feedstock

Part 1

- Crude oil, hydrocarbons and alkanes

Crude oil, hydrocarbons and alkanes

Crude oil is a **finite resource** found in rocks. Crude oil is the remains of an **ancient biomass** consisting mainly of **plankton** that was **buried in mud**.

The two definitions below are very important you must learn both of them

Crude oil is a mixture of a very large number of compounds.

Most of the compounds in crude oil are **hydrocarbons**, which are **molecules** made up of **hydrogen and carbon only.**

Crude oil, hydrocarbons and alkanes

Most of the hydrocarbons in crude oil are hydrocarbons called **alkanes**. The general formula for the homologous series of alkanes is C_nH_{2n+2}

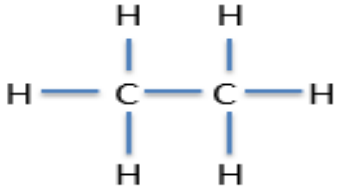
The first four members of the alkanes are methane, ethane, propane and butane.

Worked examples

Methane has one carbon atom so it's formula will be $C_1H_{(2x1)+2}$ this gives CH_4
Ethane has two carbon atoms so it's formula will be $C_2H_{(2x2)+2}$ this gives C_2H_6
Propane has three carbon atoms so it's formula will be $C_3H_{(2x3)+2}$ this gives C_3H_8
Butane has four carbon atoms so it's formula will be $C_4H_{(2x4)+2}$ this gives C_4H_{10}

You will be expected to know the names and formulae of these first four alkanes. You will be expected to calculate the formulae of alkanes with more than four carbons.

These can also be shown as:



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QuestionIT!

Carbon compounds as fuels and feedstock

Part 1

- Crude oil, hydrocarbons and alkanes

Crude oil, hydrocarbons and alkanes– QuestionIT

1. Crude oil is a finite resource. What does finite mean?
2. How was crude oil formed?
3. What is crude oil?
4. What is the definition of a hydrocarbon?
5. What is the general formula of the alkanes?
6. Name the first four members of the alkanes.
7. What would be the formula of an alkane with nine carbons?
8. Draw the structural formula of propane.

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AnswerIT!

Carbon compounds as fuels and feedstock

Part 1

- Crude oil, hydrocarbons and alkanes

Crude oil, hydrocarbons and alkanes– QuestionIT

1. Crude oil is a finite resource. What does finite mean?
   Being used up faster than it is being formed.
2. How was crude oil formed?
   Remains of an ancient biomass consisting of many plankton that was buried in mud.
3. What is crude oil?
   Mixture of a very large number of compounds, most of which are hydrocarbons.
4. What is the definition of a hydrocarbon?
   Compound containing hydrogen and carbon only.

5. What is the general formula of the alkanes?

   C_nH_{2n+2}

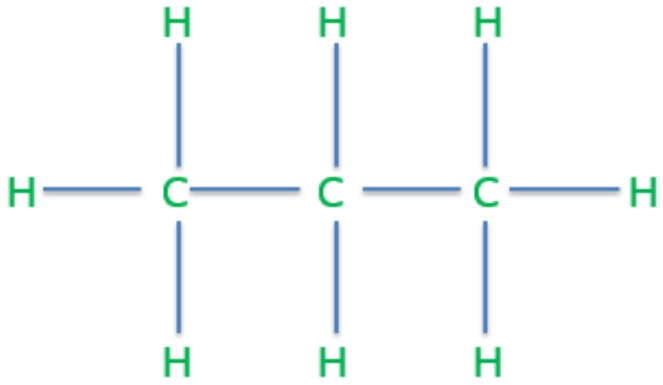
6. Name the first four members of the alkanes.

   Methane, ethane, propane, butane

7. What would be the formula of an alkane with nine carbons?

   C_9H_{20}

8. Draw the structural formula of propane.



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Carbon compounds as fuels and feedstock

Part 2

- Fractional distillation and petrochemicals
- Properties of hydrocarbons

The many hydrocarbons in crude oil may be separated into **fractions**, each of which contains molecules with a **similar number of carbon atoms** by fractional distillation

Below is a diagram of a fractional distillation column, learn the order of the fractions on the right hand side

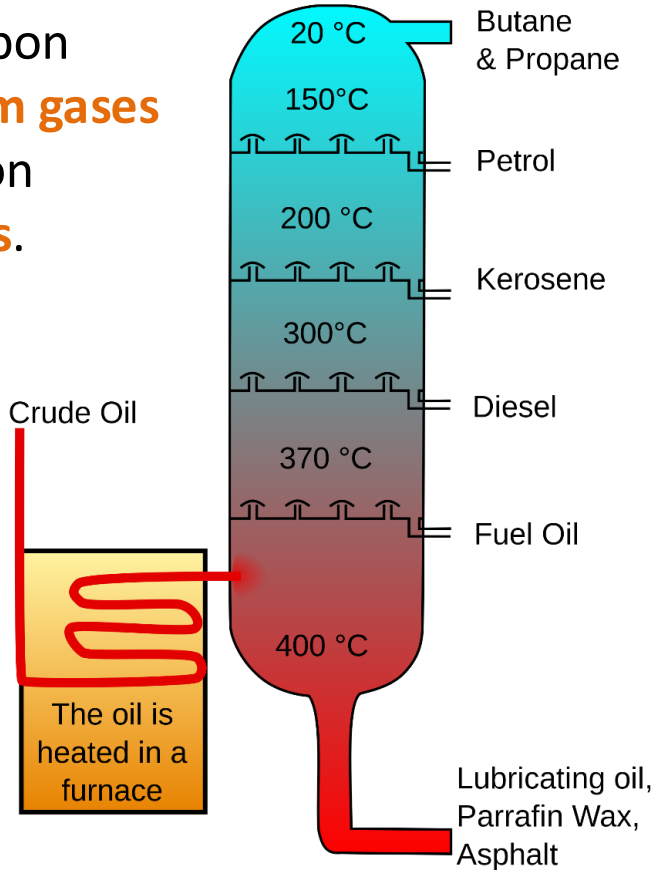
If we look at the diagram on the right all the hydrocarbon molecules in the highest fraction – **liquefied petroleum gases** will have between **1 and 4 carbons**. All the hydrocarbon molecules in **petrol** will have between **5 and 9 carbons**.

Some properties of hydrocarbons depend on the **size of their molecules**, including:

- **Boiling point**
- **Viscosity**
- **Flammability**

These change with increasing molecular size.

We know that as we go **up** the fractional distillation column the boiling point and viscosity **decrease**, the flammability **increases**.



The fractions produced in fractional distillation can be processed to produce fuels e.g. petrol, and feedstock (reactants for further chemical reactions) for the petrochemical industry.

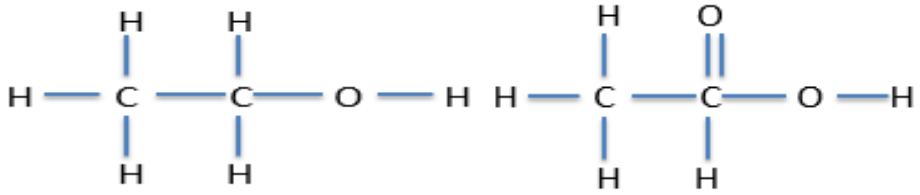
Examples of these useful materials are:

- **Solvents** – nail varnish remover
- **Lubricants** – oil for car engines
- **Polymers** – polythene and **p**oly**v**inyl **c**hloride PVC
- **Detergents** – washing up liquid

It would be helpful to know all of these useful materials and the examples for the exam.

The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds.

Examples of this are ethanol C_2H_5OH and ethanoic acid CH_3COOH. Both contain two carbon atoms, but they make very different compounds with very different properties. This would also be the case for molecules with three or four etc. carbon molecules.



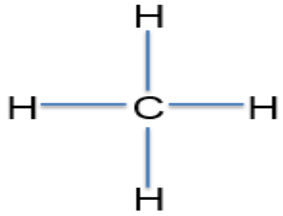
Ethanol

Ethanoic acid

The **combustion** of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are **oxidised**. The **complete combustion** of a hydrocarbon produces **carbon dioxide** and **water** e.g.

Methane + oxygen → carbon dioxide + water

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + H_2O(l)$$



If we look at methane we can see that to make carbon dioxide and water all of the carbon and hydrogen bonds must break, these will then make carbon and oxygen bonds for carbon dioxide i.e. the **carbon is oxidised** and hydrogen and oxygen bonds for the water i.e. the **hydrogen is oxidised**.

The examination boards states that students should be able to write **balanced equations** for the complete combustion of hydrocarbons with a given formula.

Worked Example

What is the balanced symbol equation for the combustion of C_9H_{20}

$$C_{11}H_{24} + 17O_2 \rightarrow 11CO_2 + 12H_2O$$

The number in front of **CO_2 is always the subscript from the alkane for carbon** e.g. 11

The number in front of **H_20 is always half the subscript from the alkane for hydrogen** e.g. 12

We then **add up the number of oxygen atoms** we now have as products e.g. 22 from CO_2 and 12 from H_2O which gives 34, we then **put half this number in front of O_2** e.g. $17O_2$

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Carbon compounds as fuels and feedstock

Part 2

- Fractional distillation, Petrochemicals and Properties of hydrocarbons

1. What do we call the many hydrocarbons in crude oil?

2. How can the hydrocarbons in crude oil be separated out?

3. The hydrocarbons in crude oil can be processed to produce…

4. List the following fractions from fractional distillation in order of boiling point, the fraction with the lowest boiling point should be first.
   Kerosene, diesel oil, heavy fuel oil, liquefied petroleum gases, petrol.

5. Give three examples of useful materials produced by the petrochemical industry.

6. How would you describe the boiling point, the viscosity and the flammability of a very large alkane molecule?

7. Nonane C_9H_{20} was combusted in oxygen to produce carbon dioxide and water. Write the balanced symbol equation for this reaction.

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AnswerIT!

Carbon compounds as fuels and feedstock

Part 2

- Fractional distillation, Petrochemicals and Properties of hydrocarbons

1. What do we call the many hydrocarbons in crude oil?
   Fractions.
2. How can the hydrocarbons in crude oil be separated out?
   Fractional distillation.
3. The hydrocarbons in crude oil can be processed to produce…
   Fuels and feedstock.
4. List the following fractions from fractional distillation in order of boiling point, the fraction with the lowest boiling point should be first.
   Kerosene, diesel oil, heavy fuel oil, liquefied petroleum gases, petrol.
   LPG, petrol, diesel oil, kerosene, heavy fuel oil

6. Give three examples of useful materials produced by the petrochemical industry.
   Solvents, lubricants, polymers, detergents.
7. How would you describe the boiling point, the viscosity and the flammability of a very large alkane molecule?
   High boiling point, high viscosity, low flammability.
8. Nonane C_9H_{20} was combusted in oxygen to produce carbon dioxide and water. Write the balanced symbol equation for this reaction.
   $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

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Carbon compounds as fuels and feedstock

Part 3

- Cracking and alkenes

Cracking and alkenes

Hydrocarbons can be broken down (cracked) to produce smaller **more useful** molecules.

This is a very important definition.

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

The two products made are both more useful than the starting hydrocarbon, but notice that there are always the **same number** of carbons and hydrogens on the left hand side of the equation and on the right hand side.

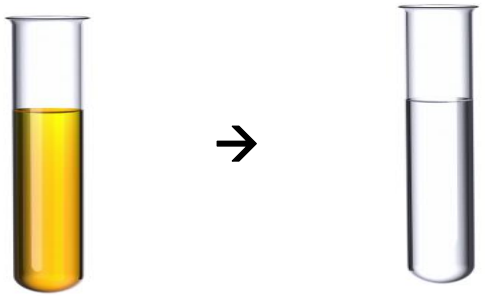
Cracking can be done by various methods including:
Catalytic cracking – the hydrocarbon is heated to a high temperature and a catalyst used
Steam cracking – the hydrocarbon is heated and mixed with steam

Cracking and alkenes

The products of cracking include alkanes and another type of hydrocarbon called **alkenes**.

Alkenes are **more reactive** than alkanes and react with **orange-brown bromine water** to turn it **colourless**. There is a high demand for fuels with small molecules and so some of the products of cracking are useful as fuels.

The test for an alkene



Orange/brown bromine water → **Turns colourless when alkene is added**

Alkenes are used to produce **polymers** and as starting materials for the production of many other chemicals.

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Carbon compounds as fuels and feedstock

Part 3

- Cracking and alkenes

1. Define the term ‘cracking’.

2. Name two methods of cracking.

3. What are the conditions needed for cracking?

4. Which are more reactive: alkanes or alkenes?

5. What is the test for alkenes?

6. Complete the following equation for a cracking reaction.

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AnswerIT!

Carbon compounds as fuels and feedstock

Part 3

- Cracking and alkenes

1. Define the term ‘cracking’.
   Breaking hydrocarbons down to produce smaller, more useful molecules.
2. Name two methods of cracking.
   Catalytic, steam
3. What are the conditions needed for cracking?
   High temperature + catalyst
4. Which are more reactive: alkanes or alkenes?
   Alkenes
5. What is the test for alkenes?
   Bromine water; orange to colourless
6. Complete the following equation for a cracking reaction.

$$C_{14}H_{30} \longrightarrow C_{11}H_{24} + C_3H_6$$

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Reactions of alkenes (Chemistry only)

- Structure and formulae of alkenes
- Reactions of alkenes

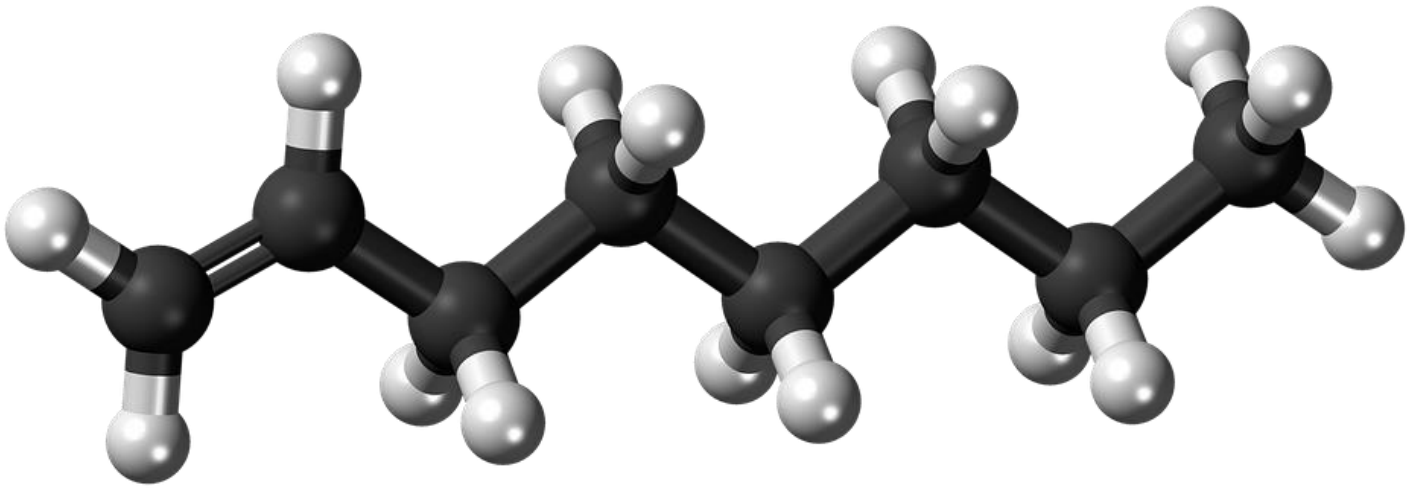
Structure and formulae of alkenes (Chemistry only)

We already know that alk**anes** have the general formulae C_nH_{2n+2}

Alk**enes** are hydrocarbons with a **double carbon-carbon bond**. The general formula for the homologous series of alkenes is C_nH_{2n}

The first four members of the alkanes are ethene, propene, butene and pentene.

There is no chemical called methene, as the double bond must be between two carbons. Any hydrocarbon starting with meth- can only have one carbon.



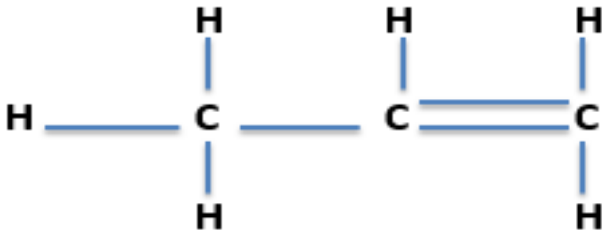
Structure and formulae of alkenes (Chemistry only)

Worked examples

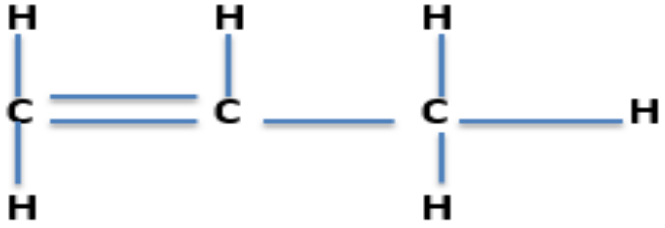
Ethene has two carbon atoms so it's formula will be $C_2H_{(2x2)}$ this gives C_2H_4
Propene has three carbon atoms so it's formula will be $C_3H_{(2x3)}$ this gives C_3H_6
Butene has four carbon atoms so it's formula will be $C_4H_{(2x4)}$ this gives C_4H_8
Propene has five carbon atoms so it's formula will be $C_5H_{(2x5)}$ this gives C_5H_{10}

You will be expected to know the names and formulae of these first four alkenes, you will be expected to calculate the formulae of alkenes with more than five carbons

Where the double bond is placed is not important at this stage so for propene we can draw it in one of two ways e.g.



Or



Both are C_3H_6

Reaction of alkenes (Chemistry only)

Alkenes are hydrocarbons with the functional group  . This is the **carbon-carbon double bond**.

Alkenes react with oxygen in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with **smoky flames** because of **incomplete combustion**.

Alkenes can therefore react as alkanes do e.g.

butene + oxygen → carbon dioxide + water

$$C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$$

Incomplete combustion however produces either carbon monoxide CO or carbon C i.e.

$$C_4H_8 + 4O_2 \rightarrow 4CO + 4H_2O$$

Or

$$C_4H_8 + 2O_2 \rightarrow 4C + 4H_2O$$

Alkenes react with hydrogen, water and the halogens (chlorine, bromine and iodine) by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond.

Propene + hydrogen → propane

Propene + water → propanol

Propene + chlorine → chloropropane

QuestionIT!

Reactions of alkenes (Chemistry only)

- Structure and formulae of alkenes
- Reactions of alkenes

Structure, formula and reactions of alkenes (Chemistry only) QuestionIT

1. What type of bond do all alkenes contain?

2. What is the general formula for the homologous series of alkenes?

3. Why are alkenes unsaturated?

4. What are the first four members of the homologous series of alkenes?

5. What would be the formula of an alkene that contained 18 hydrogen atoms?

6. Draw the structural formula of butane C_4H_8

7. Write the balanced symbol equation for the incomplete combustion of octane C_8H_{16} to produce carbon monoxide and water.

8. What alcohol will be produced when water reacts with butane?

9. What chemical is produced when bromine reacts with pentene?

AnswerIT!

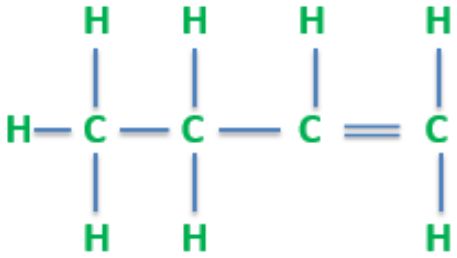
Reactions of alkenes (Chemistry only)

- Structure and formulae of alkenes
- Reactions of alkenes

Structure, formula and reactions of alkenes (Chemistry only) QuestionIT

1. What type of bond do all alkenes contain?
   C=C
2. What is the general formula for the homologous series of alkenes?
   C_nH_{2n}
3. Why are alkenes unsaturated?
   Contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms.
4. What are the first four members of the homologous series of alkenes?
   Ethene, propene, butane, pentene.
5. What would be the formula of an alkene that contained 18 hydrogen atoms?
   $C_{18}H_{36}$

6. Draw the structural formula of butane C_4H_8



The double bond could be between any two carbons, but make sure each carbon only has 4 bonds.

7. Write the balanced symbol equation for the incomplete combustion of octane C_8H_{16} to produce carbon monoxide and water.

$$C_8H_{16} + 8O_2 \rightarrow 8CO + 8H_2O$$

6. What alcohol will be produced when water reacts with butane?
   Butanol
7. What chemical is produced when bromine reacts with pentene?
   Bromopentane

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Reactions of alcohols and Carboxylic acids (Chemistry only)

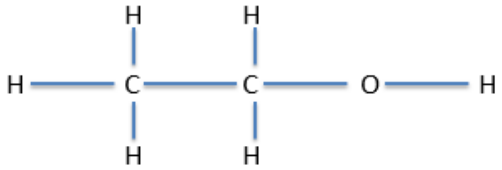
- **Reaction of alcohols**
- **Reactions of carboxylic acids**

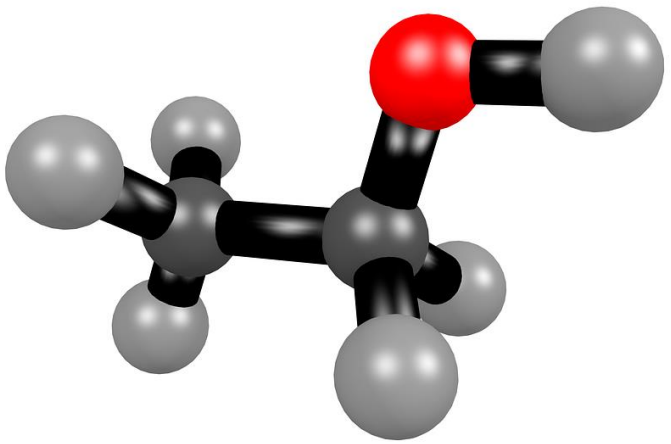
Reactions of alcohols (Chemistry only)

Alcohols contain the functional group **-OH**

Methanol has the formula CH_3OH
Ethanol has the formula CH_3CH_2OH or C_2H_5OH
Propanol has the formula $CH_3CH_2CH_2OH$ or C_3H_7OH
Butanol has the formula $CH_3CH_2CH_2CH_2OH$ or C_4H_9OH

An alternative way to show the alcohol structure is:





Reactions of alcohols (Chemistry only)

Alcohols have a number of important reactions:

- When **ethanol reacts with sodium,** bubbles of **hydrogen gas** are given off and colourless **sodium ethoxide** solution is left

Sodium + ethanol → sodium ethoxide + hydrogen

- All the alcohols **dissolve in water** to give **colourless solutions** with a **pH of 7**.
- Alcohols can react with an **oxidising reagent** to make the **carboxylic acid** e.g. **ethanol** will oxidise to make **ethanoic acid**.
- Alcohols also undergo **combustion** reactions with oxygen e.g.

Propanol + oxygen → carbon dioxide + water

$$C_3H_7OH + 5O_2 \rightarrow 3CO_2 + 4H_20$$

Aqueous solutions of ethanol are produced when sugar solutions are fermented using yeast.

The conditions needed for **fermentation** to happen are:

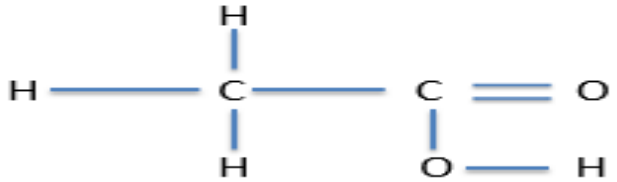
- A **temperature** between **25^{O}C and 45^{O}C**
- **Water** but **no oxygen**

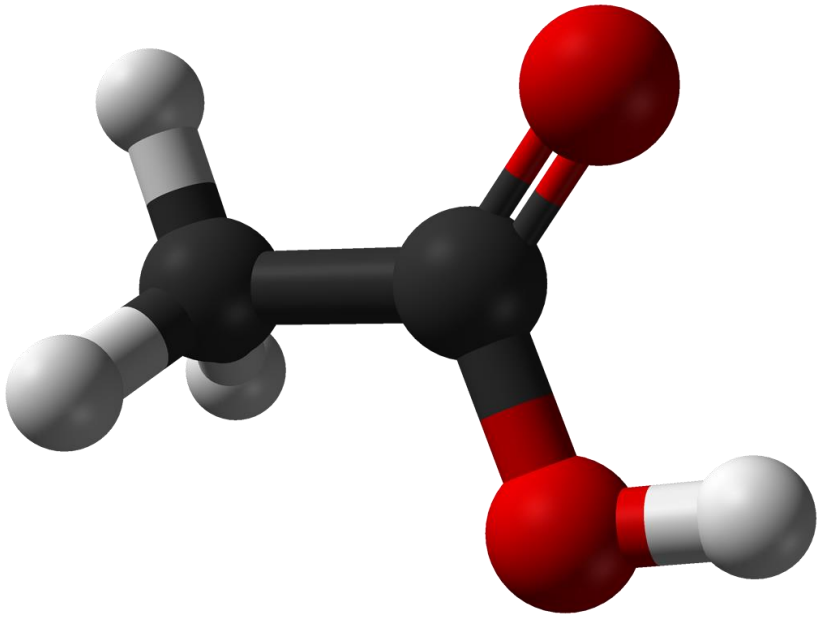
Reactions of carboxylic acids (Chemistry only)

Carboxylic acids have the functional group **-COOH**

Methanoic acid has the formula CHOOH
Ethanoic acid has the formula CH_3COOH
Propanoic acid has the formula C_2H_5COOH
Butanoic acid has the formula C_3H_7COOH

An alternative way to show the carboxylic acid structure is:





Reactions of carboxylic acids (Chemistry only)

Carboxylic acids have a number of important reactions:

- When we react carboxylic acids with a **metal carbonate** a **salt, carbon dioxide** and **water** are produced e.g.
  Sodium carbonate + propanoic acid → sodium propanoate + carbon dioxide + water
- Carboxylic acids with **five or less carbons dissolve in water.** Carboxylic acids with **more than five carbons in them are less soluble**.
- Carboxylic acids will **react with alcohols** to make an **ester and water**, an **acid catalyst** is needed (ethyl ethanoate is the ester below)
  Ethanoic acid + ethanol → ethyl ethanoate + water

(HT only)
Carboxylic acids are described as **weak acids** as they are only **partially ionised**, therefore they give off relatively **few hydrogen ions** in comparison to strong acids and have a **higher pH** than strong acids.

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Reactions of alcohols and Carboxylic acids (Chemistry only)

- Reaction of alcohols
- Reactions of carboxylic acids

1. Name and give the formulae of the first three alcohols.

2. What is the functional group that all alcohols contain?

3. What are the conditions needed for sugar to ferment into alcohol?

4. Write a word equation for the reaction between ethanol and oxygen.

5. Write a word equation for the reaction between ethanol and sodium.

6. What is the functional group that all carboxylic acids contain?

7. Name the first four members of the homologous series of carboxylic acids.

8. Name and give the formula of the carboxylic acid that contains four carbon atoms.

9. Draw the structural formula of propanoic acid.

10. Which two chemicals are made when an alcohol and a carboxylic acid are reacted together?

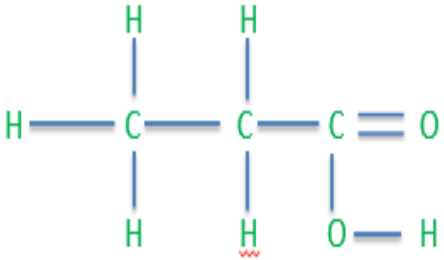
AnswerIT!

Reactions of alcohols and Carboxylic acids (Chemistry only)

- Reaction of alcohols
- Reactions of carboxylic acids

1. Name and give the formulae of the first three alcohols.
   methanol CH_3OH, ethanol C_2H_5OH, propanol C_3H_7OH
2. What is the functional group that all alcohols contain?
   -OH
3. What are the conditions needed for sugar to ferment into alcohol?
   No oxygen, temperature between 25^{O}C and 45 ^{O}C, water and yeast.
4. Write a word equation for the reaction between ethanol and oxygen.
   Ethanol + oxygen → carbon dioxide and water
5. Write a word equation for the reaction between ethanol and sodium.
   Ethanol + sodium → sodium ethoxide + hydrogen

6. What is the functional group that all carboxylic acids contain?
   -COOH
7. Name the first four members of the homologous series of carboxylic acids.
   Methanoic acid, ethanoic acid, propanoic acid, butanoic acid.
8. Name and give the formula of the carboxylic acid that contains four carbon atoms.
   Butanoic acid.
9. Draw the structural formula of propanoic acid.



10. Which two chemicals are made when an alcohol and a carboxylic acid are reacted together?
    Ester and water

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Synthetic and naturally Occurring polymers (Chemistry only)

- **Addition polymerisation**
- **condensation polymerisation (HT only)**
- **Amino acids (HT only)**

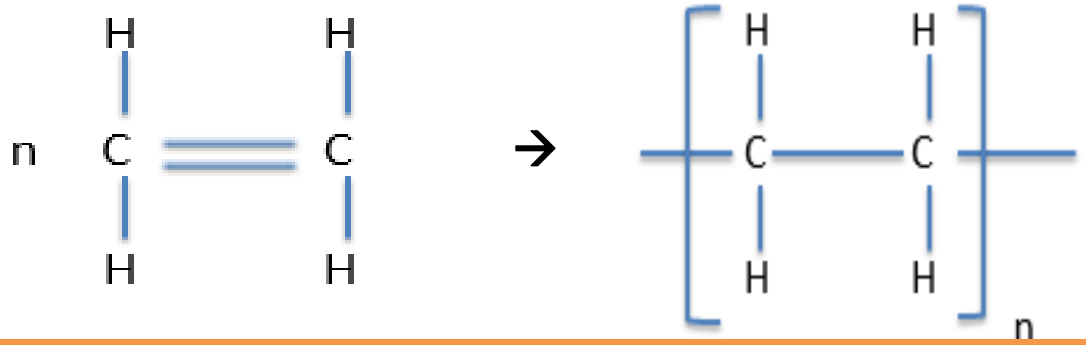
Addition polymerisation (Chemistry only)

Alkenes can be used to make **polymers** such as poly(ethane) and poly(propene) by **addition polymerisation.**

In addition polymerisation reactions, **many small molecules** (monomers) **join together** to form **very large molecules** (polymers).

Polythene has many uses.

An example of this is



One of the double bonds in the monomer breaks to form a single bond with other monomers. This leads to a very long polymer.

In **addition polymers** the repeating unit, **n,** has the **same atoms as the monomer** because no other molecule is formed in the reaction.

You must be able to move from the monomer to the polymer or polymer to the monomer

Condensation, polymerisation and amino acids (Chemistry HT only)

Condensation polymerisation involves **monomers with two functional groups**. When these types of monomers react they join together, usually **losing small molecules** such as **water**, and so the reactions are called **condensation reactions.**

The simplest polymers are produced from **two different monomers** with two of **the same functional groups** on each monomer.

An example of this is:

Ethane diol (this is ethane with two –di – alcohol – ol groups at either end)

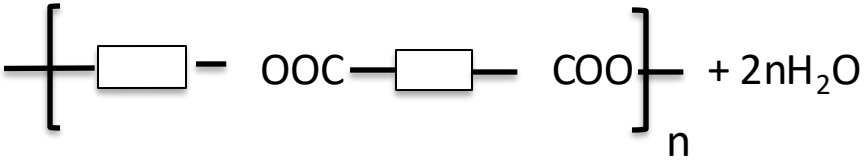
$HO – CH_2 – CH_2 – OH$ **or** HO - □ - OH

And

Hexanedioic acid (this is hexane with two carboxylic acid groups at the end)

$HOOC - CH_2 - CH_2 - CH_2 - CH_2 – COOH$ **or** HOOC - □ - COOH

Polymerise to produce a polyester

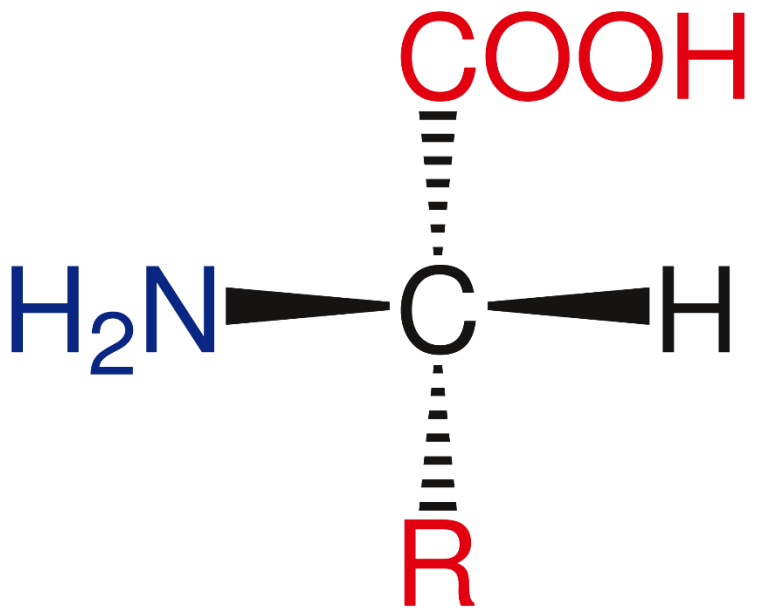
n HO - □ -OH + n HOOC - □ - COOH →  + $2nH_2O$

Condensation, polymerisation and amino acids (Chemistry HT only)

Amino acids have **two different functional groups** in a molecule. Amino acids react by condensation polymerisation to produce **polypeptides**.

e.g. glycerine is H_2NCH_2COOH and polymerises to produce the polypeptide (-$HNCH_2COO$-)n and n H_2O

Different amino acids can be combined in the same chain to produce **proteins.**



QuestionIT!

Synthetic and naturally Occurring polymers (Chemistry only)

- Addition polymerisation
- condensation polymerisation (HT only)
- Amino acids (HT only)

1. What is polymerisation?

2. What type of polymerisation joins alkenes together to make polymers?

3. What is the monomer called which forms the polymer poly(ethene)?

4. What type of polymer would butene make and what would it be called?

5. HT ONLY - What happens during condensation polymerisation?

6. HT ONLY - Explain how amino acids polymerise to form a polypeptide.

7. HT ONLY - Name and give the formula of one amino acid that polymerises in this way.

AnswerIT!

Synthetic and naturally Occurring polymers (Chemistry only)

- Addition polymerisation
- condensation polymerisation (HT only)
- Amino acids (HT only)

1. What is polymerisation?
   Many monomers join to form a polymer.
2. What type of polymerisation joins alkenes together to make polymers?
   Addition polymerisation.
3. What is the monomer called which forms the polymer poly(ethene)?
   Ethene.
4. What type of polymer would butene make and what would it be called?
   Addition polymer called poly(butene).

5. HT ONLY - What happens during condensation polymerisation?
   Monomers with two functional groups; small molecules such as water are lost through 'condensation'.
6. HT ONLY - Explain how amino acids polymerise to form a polypeptide.
   Condensation polymerisation. Two functional groups, water lost by condensation.
7. HT ONLY - Name and give the formula of one amino acid that polymerises in this way.
   glycerine – H_2NCH_2COOH

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KnowIT!

Synthetic and naturally Occurring polymers (Chemistry only)

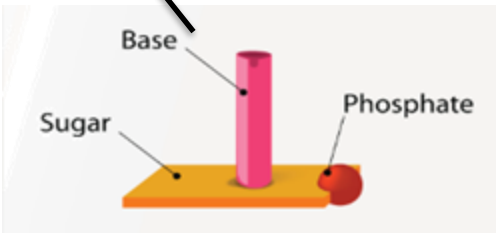
- DNA and other naturally occurring polymers

DNA and other naturally occurring polymers

DNA (deoxyribonucleic acid) is a large molecule essential for life. DNA encodes genetic instructions for the development and functioning of living organisms and viruses.

Most DNA molecules are **two polymer chains**, made from **four different monomers** called **nucleotides**, in the form of a **double helix**.

We can show the double helix structure in the following way



Each nucleotide contains a **base**, a **phosphate** and a **deoxyribose sugar**.

There are four different bases: **guanine, cytosine, thymine** or **adenine**. The nucleotide depends upon the base it contains.

There are other naturally occurring polymers:

- **Starch** and **cellulose** are both made from the **monomer glucose**
- **Proteins** are made from the **monomer amino acids**

QuestionIT!

Synthetic and naturally Occurring polymers (Chemistry only)

- DNA and other naturally occurring polymers

DNA and other naturally occurring polymers QuestionIT

1. What is DNA?
2. What does DNA do?
3. Describe the structure of DNA.
4. What are the monomers that make up DNA?
5. What three substances make up these monomers?
6. Name three other naturally occurring polymers important for life.
7. Name the monomer for protein, starch and cellulose.

AnswerIT!

Synthetic and naturally Occurring polymers (Chemistry only)

- DNA and other naturally occurring polymers

DNA and other naturally occurring polymers QuestionIT

1. What is DNA?
   Large polymer essential for life; deoxyribonucleic acid.
2. What does DNA do?
   Encodes genetic instructions for the development and functioning of living organisms and viruses.
3. Describe the structure of DNA.
   Two polymer chains, double helix.
4. What are the monomers that make up DNA?
   Nucleotides.
5. What three substances make up these monomers?
   Base, phosphate, deoxyribose sugar.
6. Name three other naturally occurring polymers important for life.
   Proteins, starch, cellulose.
7. Name the monomer for protein starch and cellulose.
   Proteins – amino acids; starch and cellulose – glucose.