

AQA GCSE Chemistry — Chemistry

Topic 7

Organic chemistry

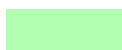
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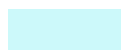
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Hydrocarbon

- a molecule made up of hydrogen and carbon atoms only.

Define Finite resource

- a resource that is being used up faster than it is being formed, so it will run out.

Define Homologous series

- a family of compounds with the same general formula and similar chemical properties.

Define Fractional distillation

- separating a mixture of liquids using their different boiling points, by evaporation and condensation in a column.

Define Viscosity

- how thick and difficult to pour a liquid is.

Define Complete combustion

- burning in plenty of oxygen, so the carbon and hydrogen in the fuel are fully oxidised to carbon dioxide and water.

Define Alkene

- **CHEMISTRY ONLY** an unsaturated hydrocarbon containing a carbon–carbon double bond, general formula C_nH_{2n} .

Define Functional group

- **CHEMISTRY ONLY** the group of atoms in a molecule that determines how it reacts, e.g. $C=C$, $-OH$, $-COOH$.

Define Monomer

- **CHEMISTRY ONLY** a small molecule that joins to others to make a polymer.

Define Crude oil

- a finite resource found in rocks; the remains of an ancient biomass consisting mainly of plankton buried in mud.

Define Alkane

- a saturated hydrocarbon with the general formula C_nH_{2n+2} .

Define Fraction

- a group of hydrocarbons separated from crude oil that contains molecules with a similar number of carbon atoms.

Define Feedstock

- a raw material used to make other useful chemicals in the petrochemical industry.

Define Flammability

- how easily a substance catches fire and burns.

Define Cracking

- breaking down large hydrocarbon molecules into smaller, more useful ones.

Define Unsaturated

- **CHEMISTRY ONLY** containing a $C=C$ double bond, so having two fewer hydrogen atoms than the alkane with the same number of carbon atoms.

Define Addition reaction

- **CHEMISTRY ONLY** a reaction in which atoms add across a $C=C$ double bond, turning it into a single bond.

Define Polymer

- **CHEMISTRY ONLY** a very large molecule made from many monomers joined together.

Define Repeating unit

- **CHEMISTRY ONLY** the section of a polymer chain that repeats over and over.

with two functional groups join, losing a small molecule such as water each time.

Define Condensation polymerisation

- **CHEMISTRY ONLY**

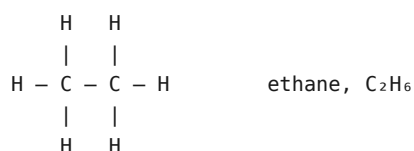
HT ONLY polymerisation in which monomers

7.1 Carbon compounds as fuels and feedstock

7.1.1 Crude oil, hydrocarbons and alkanes

- Crude oil is a finite resource found in rocks. It is the remains of an **ancient biomass consisting mainly of plankton** that was buried in mud.
- Crude oil is a mixture of a very large number of compounds. Most of them are **hydrocarbons** — molecules made up of hydrogen and carbon atoms only.
- Most of the hydrocarbons in crude oil are **alkanes**, which are **saturated** (all C–C single bonds).
- The first four members of the alkanes are methane, ethane, propane and butane. You do not need the names of any other specific alkanes.

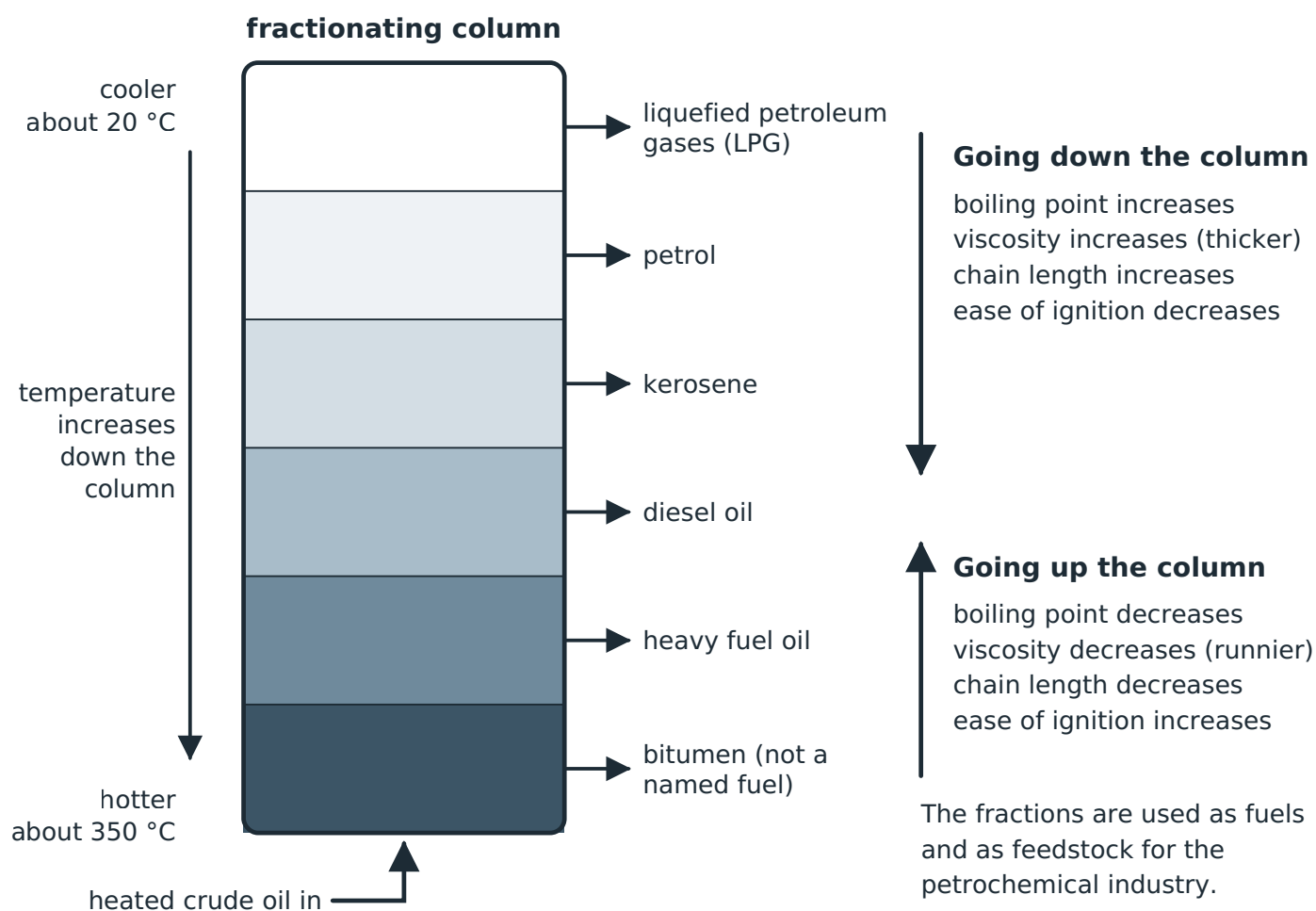
Alkanes can be written as a **molecular formula** (C₂H₆) or as a **displayed formula** showing every atom and every bond:



7.1.2 Fractional distillation and petrochemicals

- The many hydrocarbons in crude oil are separated into **fractions** by **fractional distillation**. Each fraction contains molecules with a **similar number of carbon atoms**.
- How it works — evaporation and condensation: 1. The crude oil is heated until most of it evaporates, and the vapours enter a **fractionating column**. 2. The column is hot at the bottom and cooler at the top. 3. The vapours rise up the column and condense when they reach a level that is at their boiling point. 4. Hydrocarbons with small molecules have low boiling points, so they rise high up the column before condensing; those with large molecules have high boiling points and condense near the bottom. 5. The liquid fractions are piped off at different heights.
- The fractions can be processed to produce **fuels** and feedstock for the petrochemical industry.
- Fuels produced from crude oil include petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases (LPG).
- The petrochemical industry makes many useful materials, such as solvents, lubricants, polymers and detergents.
- The vast array of natural and synthetic carbon compounds exists because carbon atoms can form families of similar compounds (homologous series), joined in chains and rings.

Fractional distillation of crude oil and the uses of the fractions



Crude oil is heated until it evaporates. The vapours rise up the column, which is cooler near the top. Each fraction condenses at a different temperature and is collected. A fraction contains molecules with a similar number of carbon atoms.

NOTE

Knowledge of the names of other specific fractions or fuels is not required — learn the five fuels and the four petrochemical products listed above.

7.1.3 Properties of hydrocarbons

Some properties of hydrocarbons depend on the size of their molecules. You must recall how these three change as the molecules get larger:

- Boiling point — increases (more energy is needed to separate the larger molecules).
- Viscosity — increases (they are thicker and flow less easily).
- Flammability — decreases (they are harder to ignite and burn less easily).

Fraction	Molecule size	Properties	Main use
Liquefied petroleum gases	Smallest (about 1–4 carbons)	Lowest boiling point, runniest, most flammable	Bottled gas for heating and cooking
Petrol	Small (about 5–10 carbons)	Low boiling point, runny, very flammable	Fuel for cars
Kerosene	Medium	Boiling point rising, more viscous, less flammable	Fuel for aircraft
Diesel oil	Large	Higher boiling point, more viscous, less flammable	Fuel for lorries, trains and some cars
Heavy fuel oil	Largest (long chains)	Highest boiling point, most viscous, least flammable	Fuel for ships and power stations

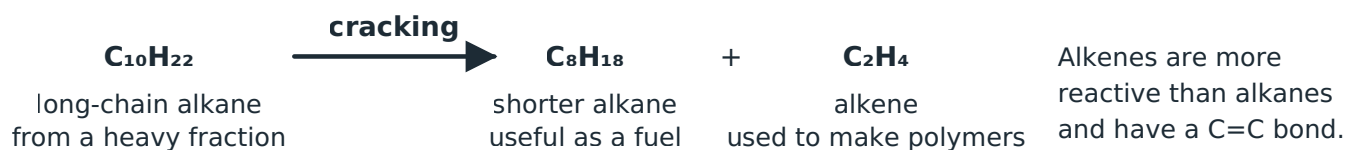
Combustion. The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuel are oxidised. **Complete combustion** of a hydrocarbon produces carbon dioxide and water:

hydrocarbon + oxygen → carbon dioxide + water

7.1.4 Cracking and alkenes

- **Cracking** breaks hydrocarbons down into **smaller, more useful molecules**. It can be done by various methods including **catalytic cracking** and **steam cracking**.
- **Catalytic cracking** — heat the long-chain hydrocarbon until it vaporises, then pass the vapour over a **hot catalyst** (about 550 °C).
- **Steam cracking** — vaporise the hydrocarbon, mix it with steam and heat to a **very high temperature** (about 850 °C).
- The products of cracking include alkanes and another type of hydrocarbon called **alkenes**.
- **Why crack?** There is a high demand for fuels with small molecules (petrol, diesel) but crude oil supplies too much of the long-chain fractions, so some products of cracking are useful as fuels. Alkenes are used to produce polymers and as starting materials for the production of many other chemicals. Modern life depends on hydrocarbons in this way — for transport fuels, plastics, solvents and detergents.
- Alkenes are more reactive than alkanes and react with bromine water, which is used as the test for alkenes.

Cracking a long-chain alkane into a shorter alkane and an alkene



Catalytic cracking

Heat the long-chain hydrocarbon to vaporise it, then pass the vapour over a hot catalyst.

Steam cracking

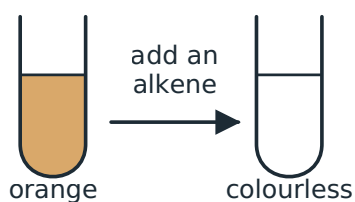
Heat the hydrocarbon to vaporise it, mix it with steam and heat it to a very high temperature.

Why crack hydrocarbons?

There is a high demand for fuels with small molecules, and cracking turns less useful long-chain hydrocarbons into shorter ones. Alkenes are used to make polymers and other useful chemicals.

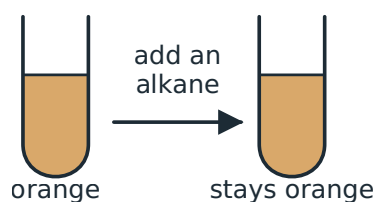
Testing with bromine water

with an alkene



Bromine water turns from orange to colourless.

with an alkane



The bromine water stays orange: no reaction. Alkenes are more reactive.

ANALOGY

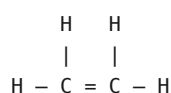
Cracking is like a timber yard with a warehouse full of **huge, unsellable planks** and a queue of customers who all want short lengths for shelving. Long hydrocarbons are in surplus, short ones are in demand, so the yard **saws the long planks up**. Heat (and the catalyst) is the saw, and every cut also produces a useful offcut — the alkene — that gets turned into something else entirely.

7.2 CHEMISTRY ONLY Reactions of alkenes and alcohols

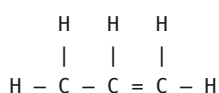
7.2.1 CHEMISTRY ONLY Structure and formulae of alkenes

- **CHEMISTRY ONLY** Alkenes are hydrocarbons with a **double carbon-carbon bond (C=C)**.
- **CHEMISTRY ONLY** Alkene molecules are **unsaturated** because they contain **two fewer hydrogen atoms** than the alkane with the same number of carbon atoms.
- **CHEMISTRY ONLY** The first four members are ethene, propene, butene and pentene. You do not need the names of any other alkenes.

CHEMISTRY ONLY Alkenes can be written as a molecular formula (C_3H_6) or as a displayed formula:



ethene, C_2H_4



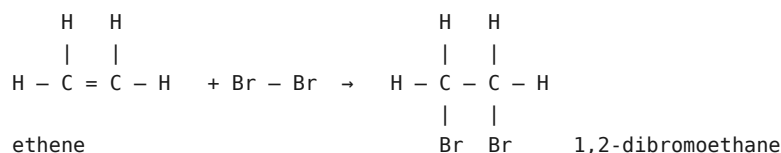
propene, C_3H_6

7.2.2 CHEMISTRY ONLY Reactions of alkenes

- **CHEMISTRY ONLY** Alkenes are hydrocarbons with the **functional group C=C**. It is the **generality of reactions of functional groups** that determines the reactions of organic compounds — every alkene reacts in the same way because every alkene has a C=C bond.
- **CHEMISTRY ONLY** 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.
- **CHEMISTRY ONLY** Alkenes react with hydrogen, water and the halogens by the addition of atoms across the carbon-carbon double bond, so that the double bond becomes a single carbon-carbon bond.

CHEMISTRY ONLY Reaction	Conditions	Product
Alkene + hydrogen	Nickel catalyst, about 150 °C	The alkane with the same number of carbons, e.g. ethene + $H_2 \rightarrow$ ethane
Alkene + water (steam)	Phosphoric acid catalyst, high temperature and high pressure	An alcohol , e.g. ethene + steam $\rightarrow$ ethanol
Alkene + halogen (chlorine, bromine or iodine)	Room temperature, no catalyst needed	A dihalo compound , e.g. ethene + $Br_2 \rightarrow$ dibromoethane (this is why bromine water is decolourised)

CHEMISTRY ONLY In the exam you may be asked to **draw the fully displayed structural formula** of the first four alkenes and the products of these additions. The double bond becomes a single bond, and the two added atoms go on the two carbons that used to share it:



7.2.3 CHEMISTRY ONLY Alcohols

- **CHEMISTRY ONLY** Alcohols contain the **functional group** -OH . The first four members of the homologous series are methanol, ethanol, propanol and butanol.
- **CHEMISTRY ONLY** Ethanol can be written $\text{CH}_3\text{CH}_2\text{OH}$, or as a displayed formula showing the -O-H group.

Recognise alcohols from names ending in **-ol** or from an **-OH** group in the formula.

CHEMISTRY ONLY Reactions of the first four alcohols

Reaction	What you observe	Products
With sodium	Fizzing; the sodium gradually disappears	Hydrogen gas and a solution of the sodium compound of the alcohol
Burning in air	Burns with a clean blue flame, releasing energy	Carbon dioxide and water (complete combustion)
Added to water	Dissolves completely	A neutral solution (pH 7)
With an oxidising agent	Solution changes as the alcohol is oxidised	A carboxylic acid , e.g. ethanol → ethanoic acid

- **CHEMISTRY ONLY Main uses.** Alcohols are used as **fuels** and as **solvents**. Ethanol is the alcohol in alcoholic drinks, and is made industrially by fermentation and by the addition of steam to ethene. Methanol is an important industrial feedstock.
- **CHEMISTRY ONLY Fermentation.** Aqueous solutions of ethanol are produced when sugar solutions are fermented using yeast. Conditions: **yeast**, an **aqueous solution of sugar**, a warm temperature of about **25–35 °C**, and the **absence of oxygen (anaerobic conditions)**. The enzymes in yeast catalyse the reaction: **sugar → ethanol + carbon dioxide**.

NOTE

CHEMISTRY ONLY You are not expected to write balanced equations for reactions of alcohols other than combustion, and you do not need the names of alcohols other than the first four.

7.2.4 CHEMISTRY ONLY Carboxylic acids

- **CHEMISTRY ONLY** Carboxylic acids have the **functional group** – **COOH**. The first four members are methanoic acid, ethanoic acid, propanoic acid and butanoic acid (names end in **-anoic acid**).
- **CHEMISTRY ONLY** Ethanoic acid is written **CH₃COOH**, or as a displayed formula in which the acid carbon is joined by a double bond to one oxygen and a single bond to an –O–H group.

CHEMISTRY ONLY Reactions of the first four carboxylic acids

- With **carbonates**: they **fizz**, producing **carbon dioxide** (which turns limewater milky), along with a salt and water. This is a useful test — carboxylic acids react with carbonates, alcohols do not.
- **Dissolved in water**: they **ionise only partially**, producing acidic solutions with a pH below 7.
- With **alcohols**, in the presence of an **acid catalyst**: they produce **esters**. Ethanoic acid + ethanol → **ethyl ethanoate**, which has a **sweet, fruity smell**. Ethyl ethanoate is the only ester you need to name.
- **HT ONLY** Carboxylic acids are **weak acids** because they are only partially ionised in aqueous solution — only a small proportion of the molecules release H⁺ ions. So at the **same concentration**, a carboxylic acid has a lower concentration of H⁺ ions and a higher pH than a strong acid such as hydrochloric acid, and reacts more slowly.

WATCH OUT

CHEMISTRY ONLY HT ONLY "Weak" is not the same as "dilute". Weak is about how much of the acid ionises; dilute is about how much acid there is in a given volume of solution. You can have a concentrated weak acid (like strong vinegar) and a dilute strong acid.

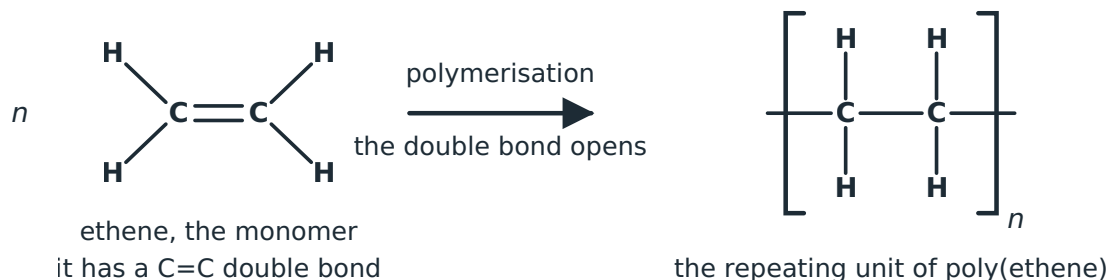
7.3 CHEMISTRY ONLY Synthetic and naturally occurring polymers

7.3.1 CHEMISTRY ONLY Addition polymerisation

- **CHEMISTRY ONLY** Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation.
- **CHEMISTRY ONLY** In addition polymerisation, many small molecules (monomers) join together to form very large molecules (polymers). The C=C double bond in each monomer opens up and joins to the next monomer.
- **CHEMISTRY ONLY** In addition polymers the repeating unit has the same atoms as the monomer, because no other molecule is formed in the reaction. So the relative formula mass of the polymer is a whole- number multiple of that of the monomer.
- **CHEMISTRY ONLY** Recognise addition monomers from the presence of the **functional group C=C**.

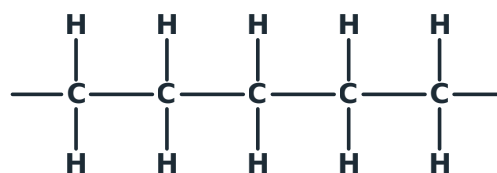
CHEMISTRY ONLY Addition polymerisation: from monomer to repeating unit

Chemistry only



Many small molecules (monomers) join together to form one very large molecule, the polymer.

The C=C double bond opens up, so no other molecule is formed: the repeating unit has the same atoms as the monomer.



part of the poly(ethene) chain — all single bonds

A monomer for addition polymerisation always contains a C=C double bond, and n stands for a very large number of repeating units. Poly(propene) is made from propene in exactly the same way.

7.3.2 CHEMISTRY ONLY

HIGHER TIER

HT ONLY Condensation polymerisation

- **CHEMISTRY ONLY HT ONLY** Condensation polymerisation involves monomers with two functional groups. When these monomers react they join together, usually losing small molecules such as water, which is why they are called **condensation** reactions.
- **CHEMISTRY ONLY HT ONLY** The simplest polymers are produced from two different monomers with two of the same functional groups on each monomer.
- **CHEMISTRY ONLY HT ONLY** Example: **ethanediol** (two –OH groups) and **hexanedioic acid** (two –COOH groups) polymerise to produce a **polyester** and **water**. Each time an –OH meets a –COOH, an **ester link** forms and one molecule of water is lost.
- **CHEMISTRY ONLY HT ONLY** For n molecules of each monomer you get one polymer chain and $2n - 1$ molecules of water (at GCSE, simply say "many molecules of water are lost").

Feature	Addition polymerisation	HT ONLY Condensation polymerisation
Monomers	One monomer, an alkene with a C=C bond	Usually two monomers, each with two functional groups (e.g. –OH and –COOH)
Products	One product only — the polymer	Two products — the polymer and a small molecule such as water
Repeating unit	Has the same atoms as the monomer	Has fewer atoms than the monomers combined; contains a link such as an ester link
Example	Ethene → poly(ethene)	Ethanediol + hexanedioic acid → polyester + water

7.3.3 CHEMISTRY ONLY

HIGHER TIER

HT ONLY Amino acids

- **CHEMISTRY ONLY HT ONLY** Amino acids have two different functional groups in a molecule — an **amino group** (–NH₂) and a **carboxylic acid group** (–COOH).
- **CHEMISTRY ONLY HT ONLY** Amino acids react by condensation polymerisation to produce polypeptides, losing a molecule of water at each join.
- **CHEMISTRY ONLY HT ONLY** For example, glycine is H₂NCH₂COOH and polymerises to produce the polypeptide with repeating unit (–HNCH₂COO–)_n.
- **CHEMISTRY ONLY HT ONLY** Different amino acids can be combined in the same chain to produce proteins.

7.3.4 CHEMISTRY ONLY DNA (deoxyribonucleic acid) and other naturally occurring polymers

- **CHEMISTRY ONLY** DNA (deoxyribonucleic acid) is a large molecule essential for life. It encodes the genetic instructions for the development and functioning of living organisms and viruses.
- **CHEMISTRY ONLY** Most DNA molecules are two polymer chains, made from four different monomers called nucleotides, in the form of a double helix.
- **CHEMISTRY ONLY** Other naturally occurring polymers important for life, and the monomers they are made from:

CHEMISTRY ONLY Natural polymer	Monomer
DNA	Nucleotides (four different ones)
Proteins	Amino acids
Starch	Glucose (a sugar)
Cellulose	Glucose (a sugar)