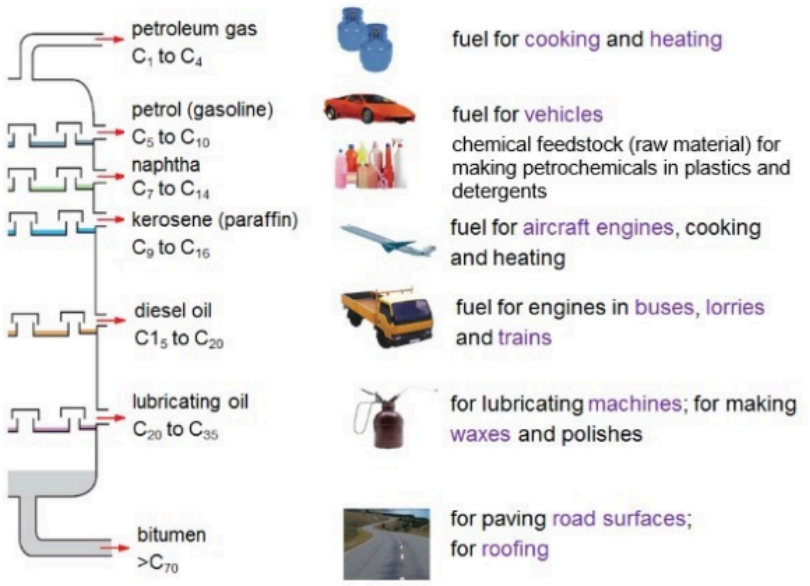
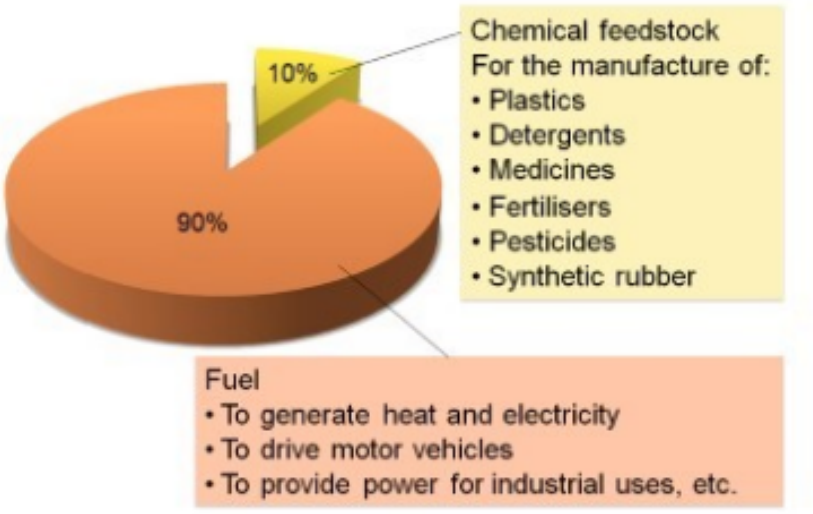
18.1 - Fuels and Crude oils

Main Sources of electricity, also known as hydrocarbons.
Formed by decomposition of plants and animals that lived millions of years ago. Hence it is finite resource

18.2 - Separation of crude oil



18.3 - Competing Uses of Different crude oil fractions



18.3.1 - Are biofuels more environmentally sustainable

Comparison of two alternatives to fossil fuels		
	Advantages	**Disadvantages**
Ethanol	a) Burns more cleanly. More complete combustion. b) Carbon neutral c) Can be cheaply produced from sugar cane/beet d) Easily stored and distributed as a liquid fuel.	a) Requires large areas of agricultural land and farmers may switch from growing food crops - increasing food prices and possible causing food shortages in third world countries. b) Produces carbon dioxide. Although it is absorbed by plants but rate of combustion is higher.
Hydrogen	a) Renewable source if obtained by electrolysis of water. Infinite supply of water b) Water is the **only** product of burning hydrogen, so it is very clean and non-polluting.	a) Although water is cheap and plentiful, it requires expensive electrical energy to electrolyse water into hydrogen and oxygen. c) Hydrogen is a gas and needs to be compressed and cooled to liquid to store and transport safely. d) Hydrogen is a highly flammable gas. e) Hydrogen is also obtained by cracking of petroleum which is a non-renewable resource.

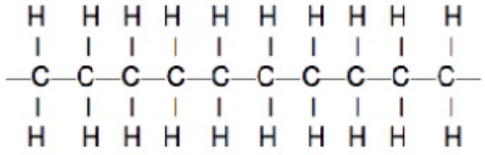
19.1 - Hydrocarbon

Definition: An organic compound which contain ONLY carbon and hydrogen

Carbon has 4 valence electrons and can bond with many other elements. Hence it can form many types of compounds. For example:

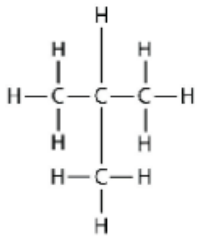
- long chain

  E.g.



- branched chain

  E.g.



- multiple bonds

  E.g. H—C≡N

- rings

  E.g.

19.1.1 - Homologous Series

Definition: A family of organic compounds with the same general formula and similar chemical properties due to the presence of same functional group

Properties:

1. Same general formula,
2. Mr differs by 14 from one member to another due to an extra CH_2 present

Increase in carbon atoms =

3. mp and bp ↑
4. Viscosity ↑
5. Density ↑
6. Solubility ↓
7. Similar chemical properties due to the presence of same functional group

19.1.2 - Naming of organic compounds

Number of carbon atoms	Prefix
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-
9	non-
10	dec-

Type of compound	**Suffix**
Alkane	**-ane**
Alkene	**-ene**
Alkyne	**-yne**
Alcohol	**-ol**
Carboxylic acid	**-oic acid**

19.1.3 - Substituent group

Definition: An atom or group of atoms that replaces a hydrogen atom on the main carbon chain.

Substituent	Formula	Prefix used in naming
Fluorine	–F	**fluoro-**
Chlorine	–Cl	**chloro-**
Bromine	–Br	**bromo-**
Iodine	–I	**iodo-**
Methyl	$–CH_3$	**methyl-**
Ethyl	$–C_2H_5$	**ethyl-**

19.1.4- Alkyl groups

Definition: Formed when you remove one hydrogen atom from an alkane.

Alkane	Alkyl group	Formula
Methane	**Methyl**	$–CH_3$
Ethane	**Ethyl**	$–C_2H_5$
Propane	**Propyl**	$–C_3H_7$
Butane	**Butyl**	$–C_4H_9$
Pentane	**Pentyl**	$–C_5H_{11}$
Hexane	**Hexyl**	$–C_6H_{13}$

19.1.5 - Same substituent group appears more than once

Number of same substituents	Prefix
2	**di-**
3	**tri-**
4	**tetra-**
5	**penta-**

19.2 - Alkanes

Definition: Saturated hydrocarbons containing only single covalent bonds between carbon atoms. (Therefore contain maximum possible number of hydrogen atoms per carbon)
General formula: C_nH_{2n+2}
End with -ane

19.2.1 - Physical properties

1. Low mp, bp as they have simple molecular structure, so the weak intermolecular forces of attraction between the molecules need only a small amount of energy to overcome
2. As number of carbon atoms increase, mp bp,density increase, (Molecular size increase)
3. More viscous (Molecular size increase)
4. As number of carbon atoms increase, less flammable and produce more soot (More carbon atoms)
5. Insoluble in water but soluble in organic solvents

19.2.2 - Chemical Reactions

1. Combustion
   In excess oxygen: Undergoes complete combustion:
   Alkane + oxygen → carbon dioxide + water

   In insufficient oxygen: Undergoes incomplete combustion:
   Alkane + insufficient oxygen → carbon monoxide + carbon + water

2. Substitution with halogens

   Alkane+halogen ->haloalkane+hydrogen halide (Requires UV light)

3. Cracking
   Definition: Breaking down large hydrocarbon molecules into smaller, more useful hydrocarbon molecules.
   Require: Al_2O_3 or SiO_2 as catalyst, 500-700℃ , 1atm
   Purpose: Produce fuel, hydrogen

19.2.3 - Isomers

Definition: Compounds that have the same molecular formula but different structural formula
Exp: C_4H_{10} may be butane or methylpropene

19.3 - Alkenes

Definition: Unsaturated hydrocarbons containing at least one (C=C)
General formula: C_nH_{2n}
End with -ene

19.3.1 - Properties

1. Low mp, bp as they have simple molecular structure, so the weak intermolecular forces of attraction between the molecules need only a small amount of energy to overcome
2. As number of carbon atoms increase, mp bp,density increase, (Molecular size increase)
3. Insoluble in water but soluble in organic solvents

19.3.2 - Chemical Reactions

1. Combustion

In excess oxygen: Undergoes complete combustion:
Alkene + oxygen → carbon dioxide + water

In insufficient oxygen: Undergoes incomplete combustion:
Alkene + insufficient oxygen → carbon monoxide + carbon + water

Compared to alkanes, higher chance of incomplete combustion and also more carbon being produced

2. Addition reaction with hydrogen (Hydrogenation)

Alkene + hydrogen → Alkane
Requires Ni as catalyst, 200℃, 1atm
Purpose: Manufacturing of Magarine

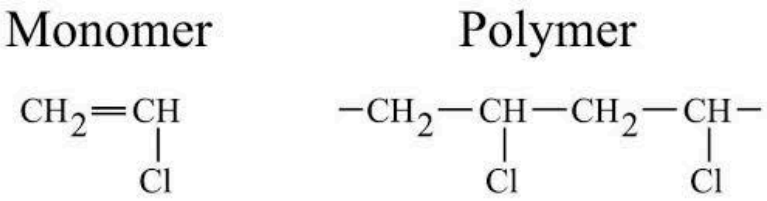
3. Addition of steam/bromine (Hydration/Bromination)

Alkene + steam → alcohol
Conditions: Steam, H_3PO_4 as catalyst, 300°C, 60–70 atm

Alkene + bromine → dibromoalkane
Solution turn from red-brown to colourless

4. Addition Polymerisation

Definition: Many alkene monomers join together to form a long-chain polymer, without producing any other product.
Requires: High pressure, high temperature, catalyst
C=C bond become a C-C bond and repeats



20.1 - Alcohols

Definition: Contain a hydroxyl functional group (–OH) attached to a carbon atom.
Is not a **hydrocarbon**
Formula: $C_nH_{2n+1}OH$
End with -ol

20.1.1 - Properties

1. Colourless
2. Higher mp bp compared to hydrocarbon that has the same number of carbon atoms
3. Very soluble for the first few (Due to -OH group present)
4. Mp Bp increase down the group, but solubility decreases (Due to molecular size)

20.1.2 - Formation of Alcohols

1. Hydration (explained in Alkene)

2. Fermentation of Glucose

Glucose → ethanol + CO_2

Requires: 40°C(No more than 40°C else enzymes would denature), Absence of oxygen
Reaction is slow but renewable, Dilute solution of ethanol (15%), Requires fractional distillation for higher purity

20.1.3 - Reactions

1. Combustion

Complete combustion:
Alcohol + oxygen → carbon dioxide + water

Burns more cleanly and completely, lesser carbon monoxide/dioxide/soot
Can be easily stored as it is liquid, renewable due to fermentation of sugar from sugar cane

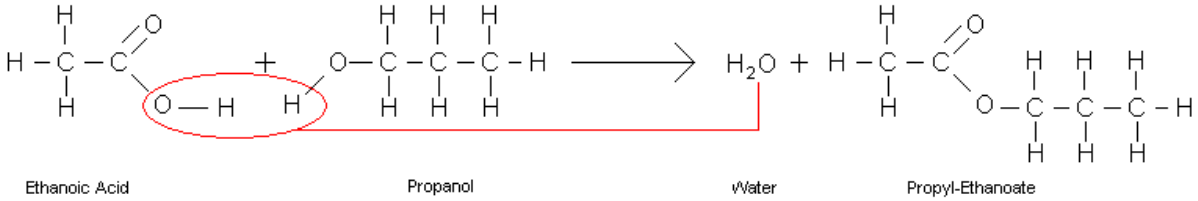
2. Oxidation of alcohols

Alcohols can be oxidised by oxygen to form carboxylic acid
Alcohol + 2[O] → Carboxylic acid + H_2O

Test for KMnO4 -> Purple to colourless (due to oxidation)

3. Esterification

Alcohol + Carboxylic acid ⇌ Ester + Water
Require: High temperature, Concentrated sulfuric acid as catalyst



20.2 - Carboxylic acid

Definition: Organic compounds containing the carboxyl functional group, –COOH.
Is not a **hydrocarbon**
Formula: $C_nH_{2n+1}COOH$
End with -oic acid

20.2.1 - Properties

1. Colourless liquid (First 4 members). Some can be coloured and in solid (Citrus acid)
2. Form a homogeneous mixture when added with water
3. Aqueous carboxylic acid have weak pH 4-6
4. Low mp bp. Increases as it goes down the group

20.2.2 - Reactions

1. React with bases to form a carboxylate salt and water

Carboxylic acid + Base → Carboxylate salt + Water

2. React with carbonates to form a carboxylate salt, carbon dioxide and water

Carboxylic acid + Carbonate → Carboxylate salt + CO_2 + H_2O

3. React with reactive metal to form a carboxylate salt and hydrogen

Carboxylic acid + Reactive metal → Carboxylate salt + H_2

4. Esterification (Explained in Alcohols)

20.2.3 - Formation of ethanoic acid

1. Oxidation by acidified KMnO4 (Oxidising Agent)

Warm ethanoic acid with acidified KMnO4. (Colour change from purple to colourless)
Ethanol act as reducing agent

2. Oxidation by atmospheric oxygen

Require: Bacteria

20.3 - Esters

Definition: Organic compounds containing the functional group –COO–.
Is not a **hydrocarbon**

20.3.1 - Formation of esters

Esterification (Explained in Alcohols)
Known as a condensation reaction which involves 2 small molecules reacting to form a large molecule with the loss of a small molecule such as water.

20.3.2 - Naming of esters

alkyl + alkanoate

Alcohol	Alkyl group	Carboxylic acid	Alkanoate	Ester name
Methanol	methyl	Methanoic acid	methanoate	**methyl methanoate**
Ethanol	ethyl	Ethanoic acid	ethanoate	**ethyl ethanoate**
Propanol	propyl	Propanoic acid	propanoate	**propyl propanoate**
Butanol	butyl	Butanoic acid	butanoate	**butyl butanoate**
Pentanol	pentyl	Pentanoic acid	pentanoate	**pentyl pentanoate**
Hexanol	hexyl	Hexanoic acid	hexanoate	**hexyl hexanoate**

20.3.3 - Uses of esters

1. Solvents for cosmetics, glues and paints
2. Used as fragrance in perfumes and fruity flavors for drinks

21.1 - Polymers

Definition: large molecules made up of many repeating smaller molecules called monomers joined together.

21.2 - How are polymers formed and used

Addition polymers are polymers formed when many unsaturated monomers, usually alkenes, join together by addition polymerisation without producing any other product.

Require: High pressure (1000atm), High temperature (200°C), Catalyst

21.2.1 - Deducing the structural formula of a polymer from its monomer

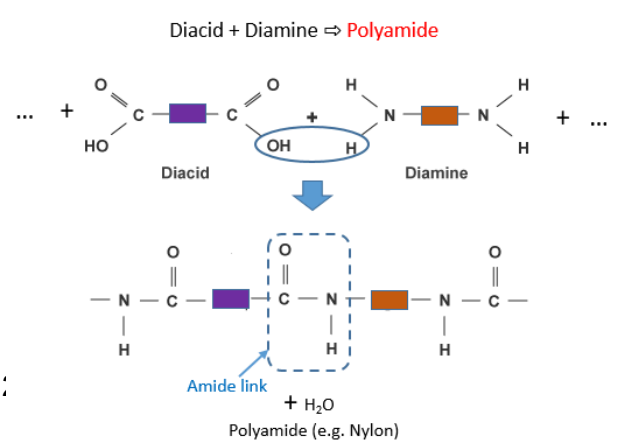
1. Rearrange the atoms such that only the middle contains the C=C bonds (any other bonds move to the top/bottom
2. Change C=C bonds into C-C bonds and add the brackets with subscript “n” after the brackets

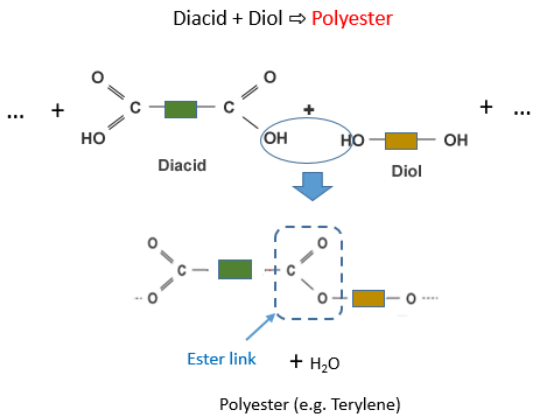
21.2.2 - Deducing the structural formula of a monomer from its polymer

1. Find the repeat unit in the polymer
2. Draw the structural formula of the repeat unit
3. Convert the C-C bond into C=C bonds

21.3 - How are Condensation Polymerisation Formed and Used

Definitions: monomers with two functional groups join together forming a polymer with the removal of a small molecule such as water





1. Identify the functional groups on each monomer.

Look for groups such as –COOH, –OH, or –NH_2.

2. Find the atoms that will join together

–COOH + –OH → ester link

–COOH + –NH_2 → amide link

3. Remove H_2O from the reacting groups.

The –OH from –COOH combines with H from –OH or –NH_2.

4. Join the monomers together using the new bond.

5. Draw the repeating unit and put it in brackets with □.

21.3.2 - Forming polyesters

1. Find the –OH groups on the diol.
2. Find the –COOH groups on the dicarboxylic acid.
3. Remove H_2O between the reacting groups.
4. Form an ester link: –COO–.
5. Repeat the structure and put it in brackets with □.

21.3.3. - Uses of Condensation Polymers

Nylon

Uses	Properties
Fibres to make strong ropes, fishing lines and nylon zippers	Very strong yet light
For making tents, parachutes, raincoat	Water resistant and not easily decomposed by bacterial or fungal attack

Terylene

Uses	Properties
As a fibre which are then woven into cloth	More resistant to wear and attack by chemicals or fungus than cotton
Often combined with cotton in fabrics and garments	Strong and resist stretching and shrinking when washed

21.4 - How does the disposal of plastics affect the environment

Advantages

- tough, waterproof and have low density / lightweight
- resistant to decay, rusting and chemical attack (thus durable).
- relatively cheap and can easily be moulded into various shapes.
- do not conduct electricity

Disadvantages

Land pollution – Plastics are non-biodegradable, so they remain in the environment for a very long time.
Marine pollution – Plastic waste can enter rivers and oceans, harming marine organisms when they become trapped in or ingest plastic.
Toxic gases from burning – Burning plastics can release harmful gases and smoke, causing air pollution.
Landfill problems – Large amounts of plastic take up space in landfills and can remain there for many years.
Microplastics – Plastics can break down into tiny pieces called microplastics, which can enter soil and water and be consumed by organisms.

21.5 - How are plastics recycled and what are the issues related to recycling plastics

Physical Method: Mechanical Recycling
Chemical Method: Cracking, Depolymersation (Monomers break down into their polymers, Polyesters undergo depolymerisation via acid hydrolysis)

21.5.1 - Issues related to recycling plastics

Environmental: Recycling uses energy and may produce carbon dioxide, contributing to pollution.
Economic: Recycling plastics can be expensive due to collection, sorting, cleaning and processing.
Social: People may be unwilling to separate and recycle their plastic waste, making recycling less effective

Stricter laws must be put in place. Recycling programs can be introduced

21.5.2 - Natural polymers

1. Fats
2. Proteins