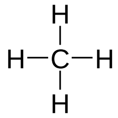
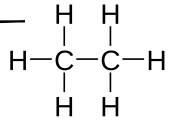
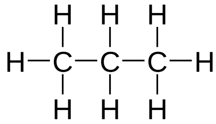
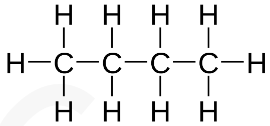
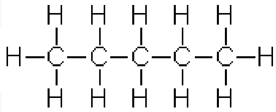
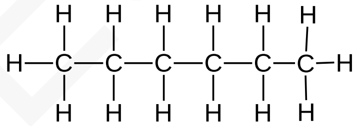
Organic Chemistry

Naming

Displayed formulae must show *all* atoms and *all* bonds

Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	
Hexane	C_6H_{14}	

Crude oil is a mixture of hydrocarbons.

A hydrocarbon is a compound containing C and H **only**

Fractional distillation

Crude oil can be separated into useful fractions by **fractional distillation**.

- The crude oil is heated until it boils.
- The **vapour** passes into a large tower (fractionating column) at the bottom.
- The temperature is higher at the bottom of the column than at the top.
- The vapour rises up the column until the fractions **condense** and are drawn off at different heights in the tower
- Fractions condense when the temperature of the column is lower than their boiling point
- The hydrocarbons with the highest boiling points (longer chains) condense towards the bottom of the tower and are drawn off there
- The smaller hydrocarbon molecules travel further up the column until they condense and are drawn off there.

fraction	use			
refinery gas	bottled gas for heating and cooking	**boiling point increases →** increasing strength **of intermolecular forces**	**liquids become more viscous →**	**colour gets darker →**
gasoline	fuel (petrol) in cars			
kerosene	used in oil stoves (paraffin) and as aircraft fuel			
diesel	fuel in diesel engines, e.g. in lorries and buses			
fuel oil	fuel for ships			
bitumen	making roads			

A fuel is a substance that, when burned, releases heat energy.

Complete combustion: when hydrocarbons burn in a plentiful supply of oxygen the products are **carbon dioxide** and **water**. E.g. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

limited supply of oxygen → incomplete combustion → carbon monoxide (CO) and soot (C) as well as water.

Carbon monoxide is a colourless, odourless gas which is very poisonous. Carbon monoxide is poisonous because it reduces the capacity of the blood to carry oxygen.

Sulfur impurities in fossil fuels – sulfur burns to produce sulfur dioxide: $S + O_2 \rightarrow SO_2$ This can react with water to form **sulfurous acid (H_2SO_3)**. Reactions in the atmosphere can convert SO_2 to **sulfuric acid (H_2SO_4)**. These are components of acid rain. This can kill trees and cause the death of fish in lakes as well as attacking buildings built of limestone.

Carbon dioxide is an important **greenhouse gas** and increases in levels of atmospheric carbon dioxide since the industrial revolution may contribute to **climate change**.

In car engines the temperatures reached are high enough to allow nitrogen and oxygen to react to form nitrogen oxides: $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ NO = nitrogen monoxide or nitric oxide
Reactions in atmosphere can convert this to nitric acid – causes acid rain

Fractional distillation of crude oil produces too many long-chain hydrocarbons – these are not in high demand and cannot be sold for much money (compared to shorter chain alkanes). **Catalytic cracking** converts long-chain alkanes to alkenes (used for making plastics) and shorter-chain alkanes (more valuable as fuels, e.g. for cars). e.g. $C_{10}H_{22} \rightarrow C_2H_4 + C_8H_{18}$
Conditions: **silica (SiO_2) or alumina (Al_2O_3)** catalyst and temperature **600-700 °C**.

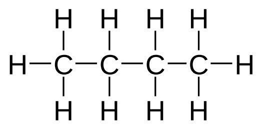
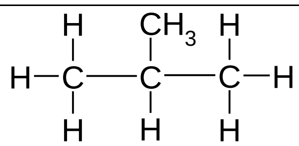
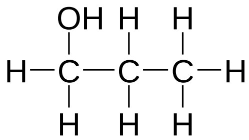
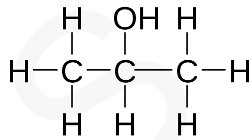
Key properties of members of a **homologous series**:

- **same functional group** therefore similar chemical properties
- members show **a gradation** in **physical** properties (e.g. melting/boiling point increase as chain gets longer).
- each member differs from the next by $–CH_2$-.
- can be described by a general formula

Functional group: atom or group of atoms in a molecule which give it its characteristic CHEMICAL properties, e.g. C=C

Isomers – compounds that have the same **molecular** formula but different **structural/displayed** formulae.

Pairs of isomers:

	
Both C_4H_{10}	
	
propan-1-ol	propan-2-ol

Alkanes – general formula: C_nH_{2n+2}. **Saturated** (only C-C single bonds) hydrocarbons

Alkanes undergo **substitution** reactions. They react with halogens in the presence of sunlight **ultraviolet radiation.**

An H atom is replaced by a halogen atom

$$CH_4 + Br_2 \xrightarrow{UV} CH_3Br + HBr$$

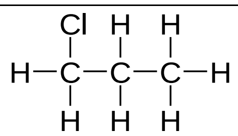
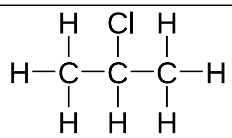
The products of the reaction are bromomethane and hydrogen bromide.

Products with Cl_2 → chloromethane and hydrogen chloride

Propane reacts with chlorine to form two organic products:

$$C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$$

C_3H_7Cl could be 1-chlorpropane or 2-chloropropane.

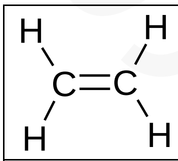
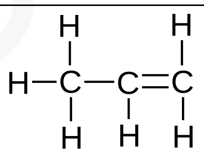
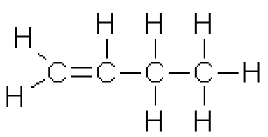
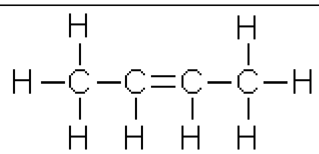
	
1-chloropropane	2-chloropropane

Alkenes – general formula: C_nH_{2n}

Saturated and Unsaturated
unsaturated contain one or more C=C (or C≡C)
saturated – only C-C
Alkenes are unsaturated, alkanes are saturated.

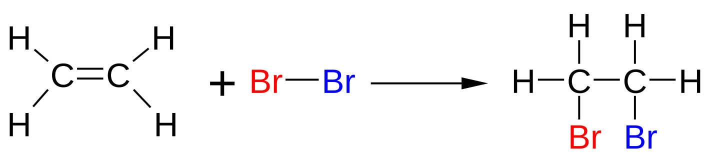
Distinguishing between saturated and unsaturated hydrocarbons:
Shake with **bromine water**:
unsaturated → colour change of bromine water from orange to colourless,
saturated → bromine water stays orange - no colour change.

Note: **not clear.**

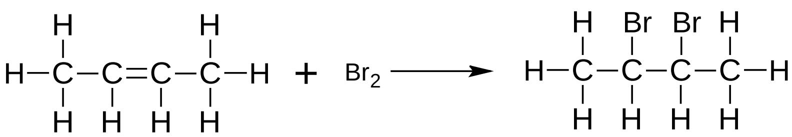
			
ethene	**propene**	but-1-ene	but-2-ene

Alkenes undergo **addition** reactions:

dibromoalkanes formed



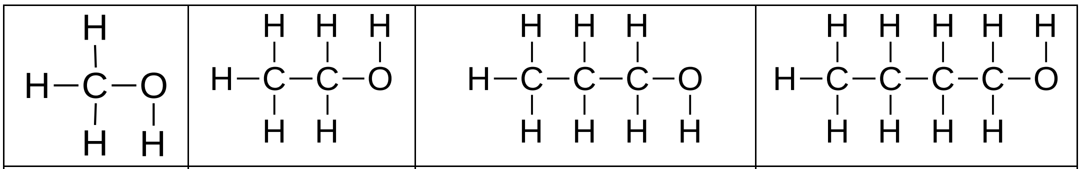
1,2-dibromoethane



2,3-dibromobutane

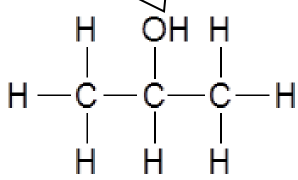
Br atoms add on to where the double bond was – only the C=C part reacts – everything else remains the same.

Alcohols –OH functional group



methanol	ethanol	propanol/propan-1-ol	butanol/butan-1-ol

Not displayed formula



propan-2-ol

Displayed formula must show O-H bond $CH_3CH_2CH_2OH$ – structural formula

Oxidation of Ethanol

Complete combustion in a plentiful supply of ***oxygen*** → complete oxidation to $CO_2 + H_2O$

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

don't forget the O in the ethanol when balancing

Microbial Oxidation - in the presence of ***oxygen*** (from air) and ***bacteria*** (*acetic acid bacteria*), ethanol is oxidised to ethanoic acid.

Chemical Oxidation Ethanol is oxidised to ethanoic acid by ***heating*** it with ***potassium dichromate(VI)*** [$K_2Cr_2O_7$] and ***sulfuric acid*** [H_2SO_4].

The potassium dichromate(VI) is the oxidising agent (changes colour from **orange** to **green** as it gets reduced)

Manufacture of Ethanol

Raw material is usually sugar/sugar cane

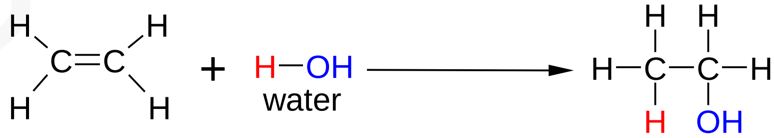
Ethanol is produced from **glucose (a sugar)** by **fermentation**. Need **yeast** - supplies **enzymes** (zymase)

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

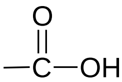
Conditions – **optimum temperature** of about 30 °C - the enzyme works best – lower temperature and reaction is too slow, higher temperatures and enzyme denatures.
Absence of air (anaerobic respiration) – in presence of O_2 ethanol is oxidised to ethanoic acid also - aerobic respiration produces just CO_2 and H_2O produced – no ethanol

Catalytic hydration of ethene

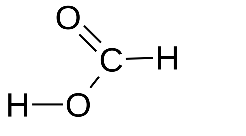
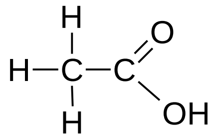
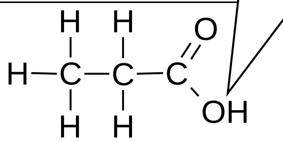
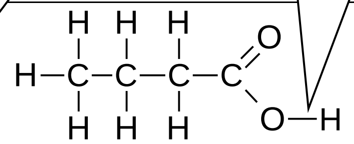
Ethene reacts with **steam** to form ethanol.
Conditions: **Steam, 300 °C, 60-70 atm., H_3PO_4 (phosphoric acid) catalyst.**



Carboxylic Acids functional group



can be written as -COOH or –CO_2H

Not displayed formula			Displayed formula
			
methanoic acid	ethanoic acid	propanoic acid	butanoic acid

Vinegar is an aqueous solution containing ethanoic acid

Reactions of carboxylic acids - dissolve in water to form acidic solutions- react in same way as other acids.

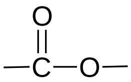
metal + acid → salt + hydrogen
carbonate + acid → salt + carbon dioxide + water

Acid	salt
Methanoic acid	methanoate
Ethanoic acid	ethanoate
Propanoic acid	propanoate
Butanoic acid	butanoate

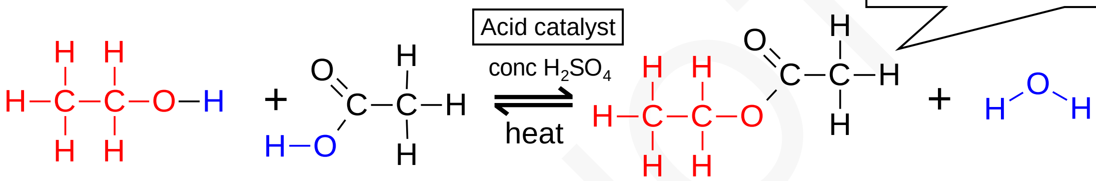
Mg + 2HCOOH → $(HCOO)_2Mg$ + H_2
magnesium methanoate

$CaCO_3(s)$ + $2CH_3COOH(aq)$ → $(CH_3COO)_2Ca(aq)$ + $CO_2(g)$ + $H_2O(l)$
Calcium ethanoate

Esters – functional group



$CH_3COOCH_2CH_3$ - *Structural formula*



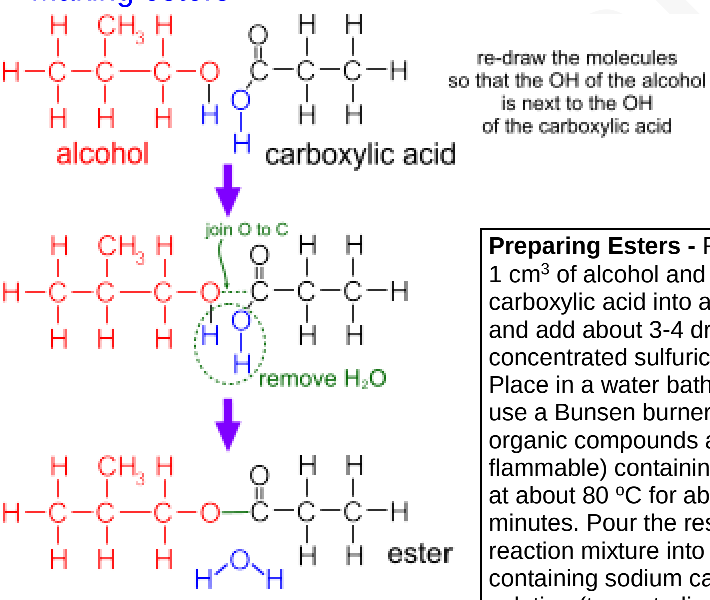
Ethanol + ethanoic acid ⇌ ethyl ethanoate + water

From alcohol

From carboxylic acid

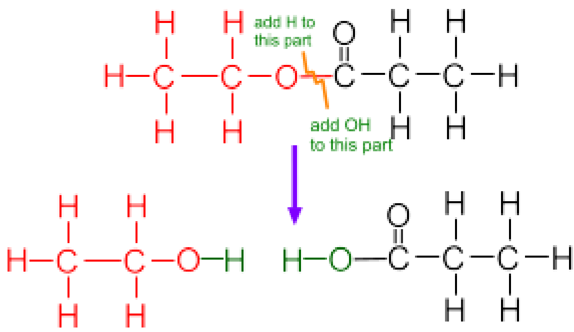
Esters are volatile (evaporate easily) compounds with sweet/fruit smell that are used in food flavourings and perfumes

Making esters



Preparing Esters - Put about 1 cm^3 of alcohol and 1 cm^3 of carboxylic acid into a test tube and add about 3-4 drops of concentrated sulfuric acid. Place in a water bath (do not use a Bunsen burner as organic compounds are flammable) containing water at about 80 ºC for about 5 minutes. Pour the resulting reaction mixture into a beaker containing sodium carbonate solution (to neutralise any remaining acid) and smell carefully.

Working out the alcohol and carboxylic acid from the ester



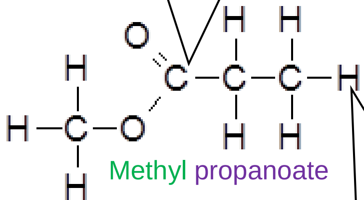
From carboxylic acid – methanoic acid

$HCOOCH_2CH_2CH_3$

propyl methanoate

From alcohol - propanol

The C with the C=O comes from the carboxylic acid



Methyl propanoate

From alcohol - methanol

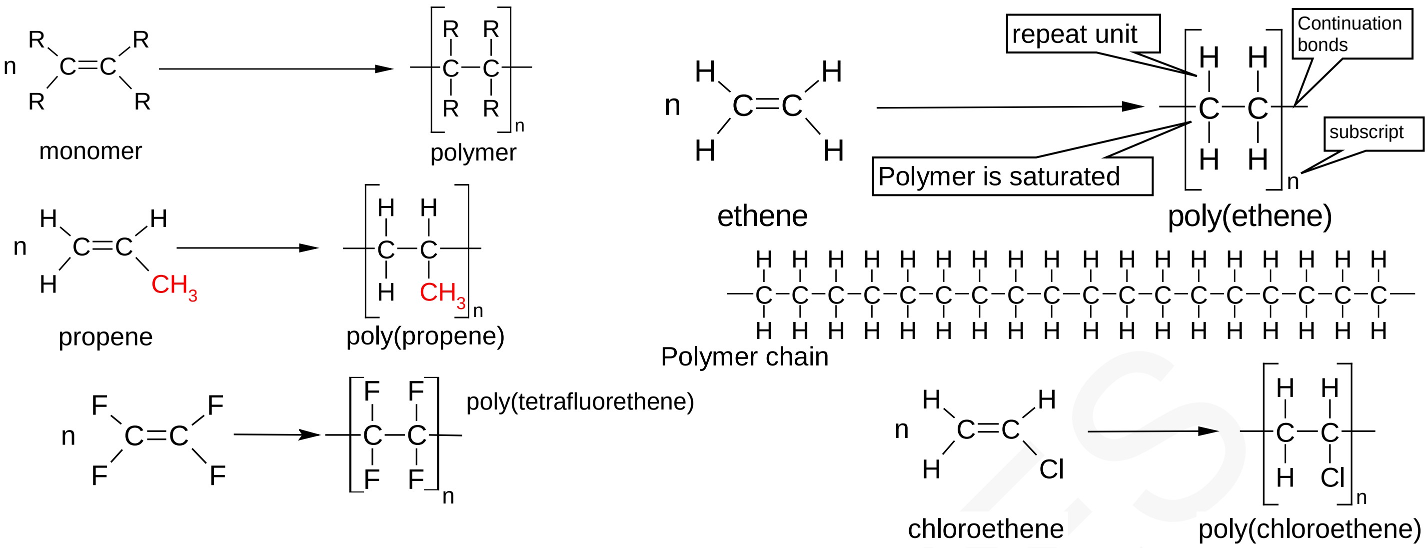
From carboxylic acid – propanoic acid

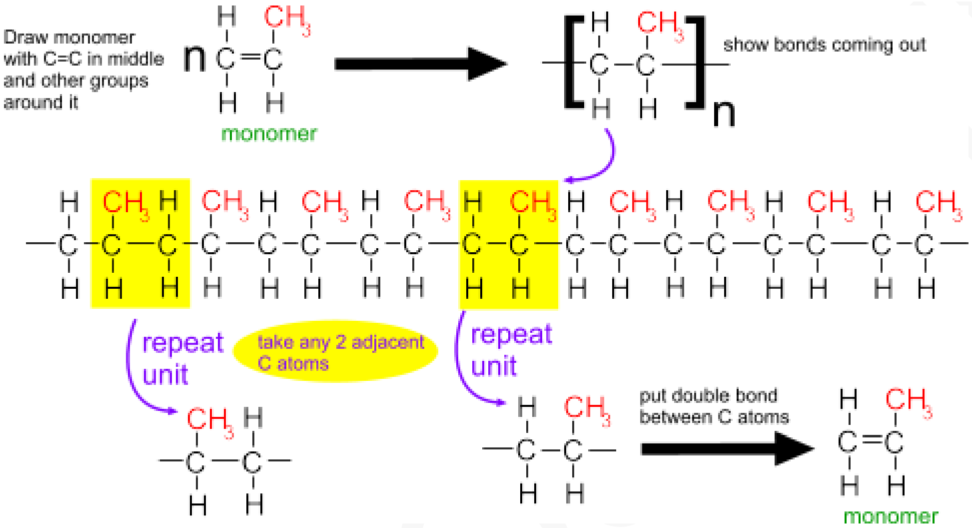
Synthetic Polymers

Addition polymerisation

Alkenes undergo addition polymerisation:

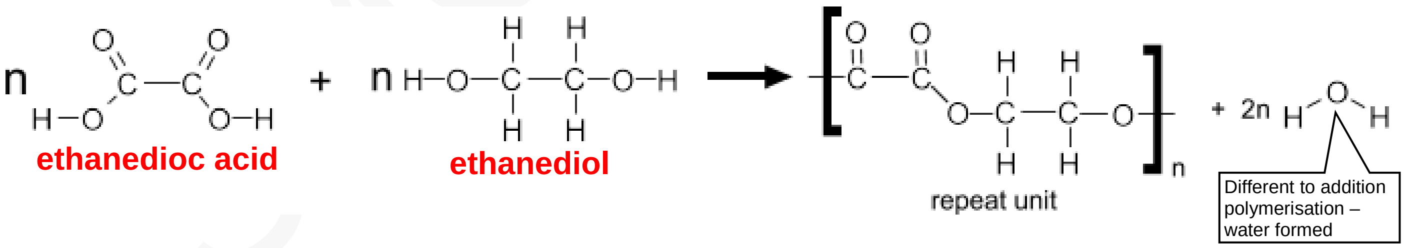
Addition polymerisation – many monomers (alkenes) added together to form a long chain – nothing lost

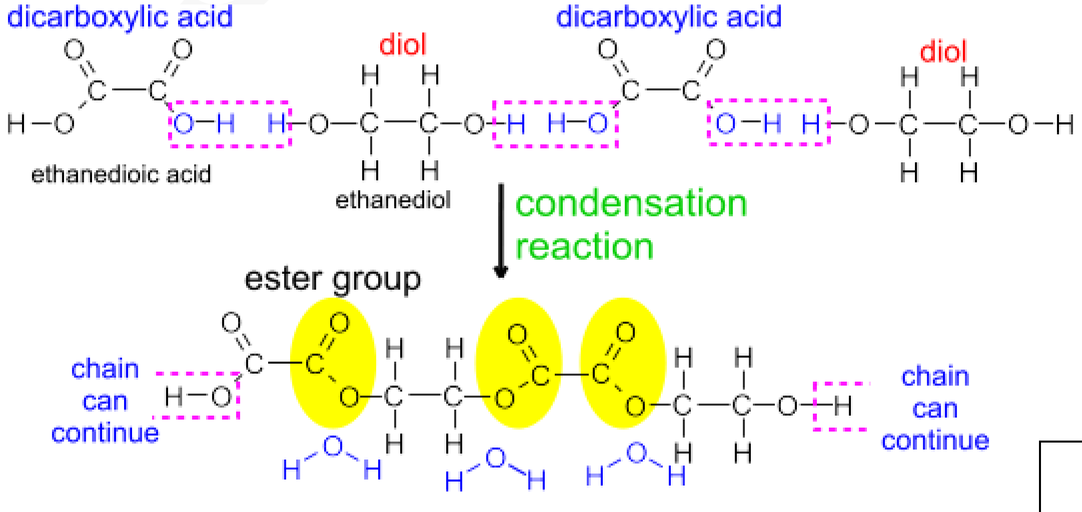




Addition polymers are hard to dispose of as they are inert and do not biodegrade. They may be disposed of by buying in landfill sites (problem as these are using up ever greater areas of land) or by burning (problem – they may give off toxic gases such as CO or HCl when burnt) and greenhouse gases such as CO_2.

Condensation polymerisation – a dicarboxylic acid reacts with a diol → a polyester and water.





Addition polymerisation
alkene monomer - 1 type of monomer- only the polymer produced

Condensation polymerisation
Dicarboxylic acid and diol monomers - two different types of monomers - small molecule (H_2O/HCl) produced as well as the polymer

Some polyesters – biopolyesters – are biodegradable