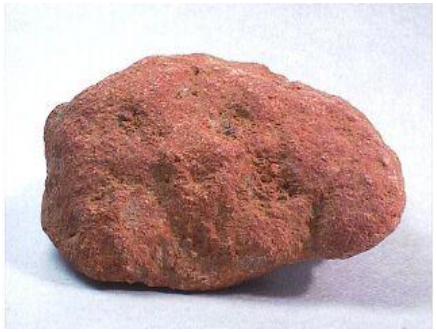


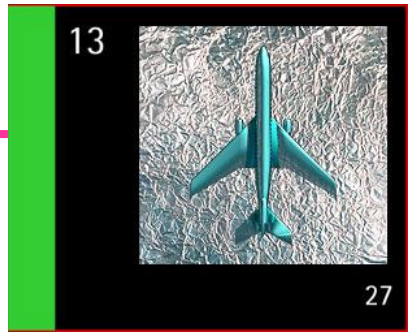
Module 16

Industrial and organic chemistry

Lesson 1

Aluminium

Aluminium – the facts



Discovered : 1825 by Hans Oersted

Isolated in Copenhagen, Denmark

Origin : From 'alumen', the Latin for the mineral alum.

- The most abundant of element.
- Does not rust and is fairly easy to recycle.
- It is lightweight but tough/strong.

Uses of aluminium

These uses require aluminium to be non-toxic and malleable (bendable)

Milk bottle tops

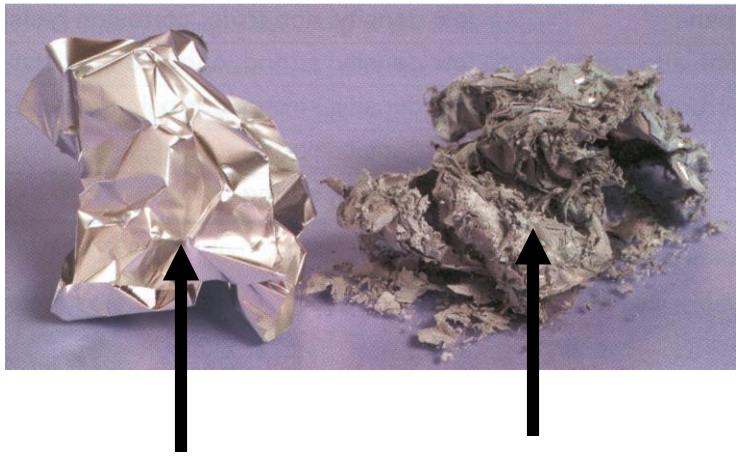
Food containers

Tear off seals on drink cartons

Cooking foil

Improving the properties of Al

Reducing the reactivity of aluminium – the oxide layer.



Aluminium with oxide layer

Aluminium without the oxide layer – becomes very reactive.

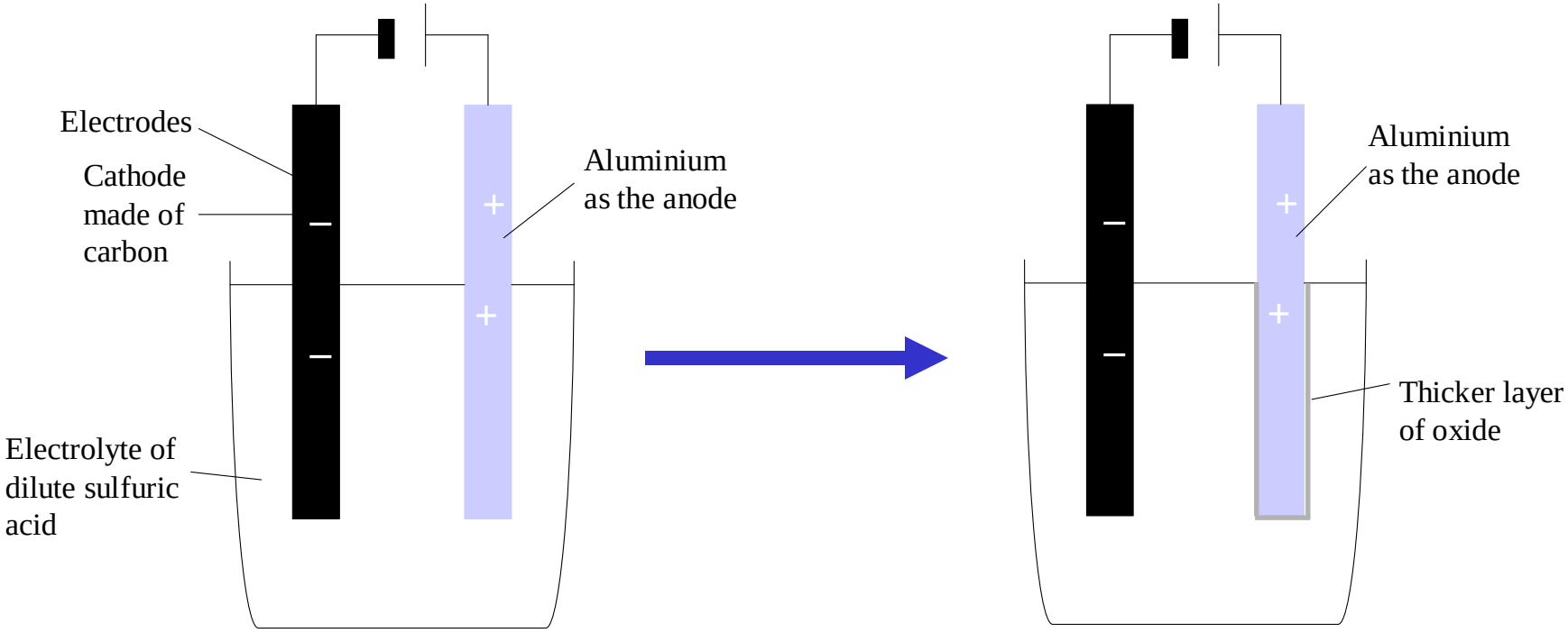
Aluminium is a reactive metal but the layer of **aluminium oxide** formed on the surface of the metal protects it against corrosion. If the oxide layer is removed by <u>amalgamating</u> it then the aluminium becomes very reactive.

Aluminium + oxygen → Aluminium oxide

$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

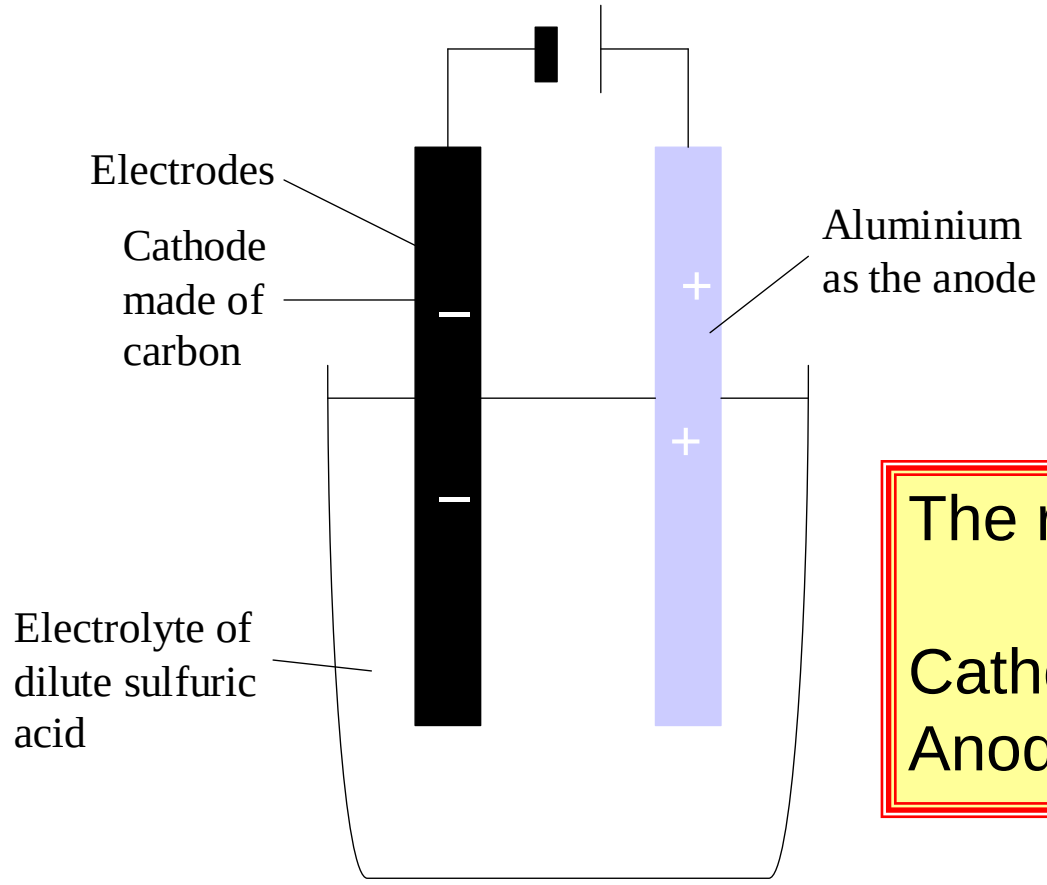
Making the oxide layer thicker

The oxide layer on the surface is made thicker using the process called **ANODISING**.



Coloured dyes can be added to the oxide layer of anodised aluminium.

Anodising in detail



The reactions at the electrodes:

Cathode: $2H^+ + 2e^- \rightarrow H_2$

Anode: $2O^{2-} \rightarrow O_2 + 4e^-$

The H^+ ions are from the sulfuric acid. The oxygen produced at the anode (aluminium) reacts with the aluminium to form a thicker coating of aluminium oxide on the surface.

Coloured dyes can be added to the oxide layer of anodised aluminium.

Improving the properties of Al

Aluminium alloys

Mixing aluminium with other metals to produce the required properties, e.g., magnesium, copper and zinc are mixed with aluminium to **increase the strength of aluminium**.

Aluminium alloys have these properties

Low density, **strong**, good conductors, corrosion resistant, non-toxic.

Uses of aluminium alloys

Electricity power lines

bicycles

Window frames

Ladders

aircraft

Kettles and pans

Summary questions

1. What method is used to extract aluminium from its ore?
2. What properties of aluminium make it ideal for used with food?
3. Aluminium is a reactive metal but what stops it corroding?
4. How can the layer of oxide on the surface of the aluminium be thickened? Describe the process?
5. What is an alloy?
6. Which metals are alloyed with aluminium?
7. Why is aluminium alloyed?
8. Why is an alloy of aluminium used for electricity power lines rather than copper wires which is a better conductor of electricity?

Lesson 2

Extracting metals

The reactivity series

Potassium
Sodium
Lithium
Calcium
Magnesium
Aluminium

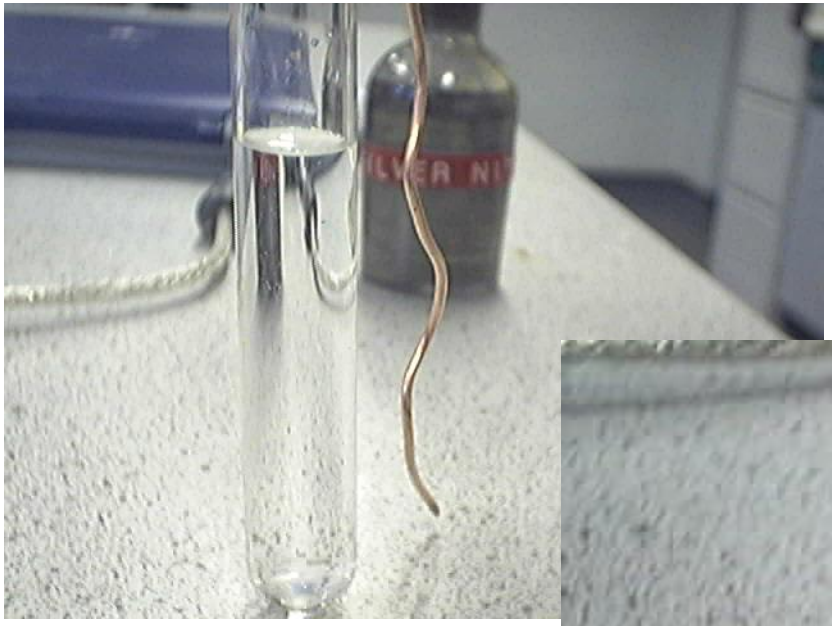
Zinc
Iron
Tin
Lead

Copper
Silver
Gold
Platinum

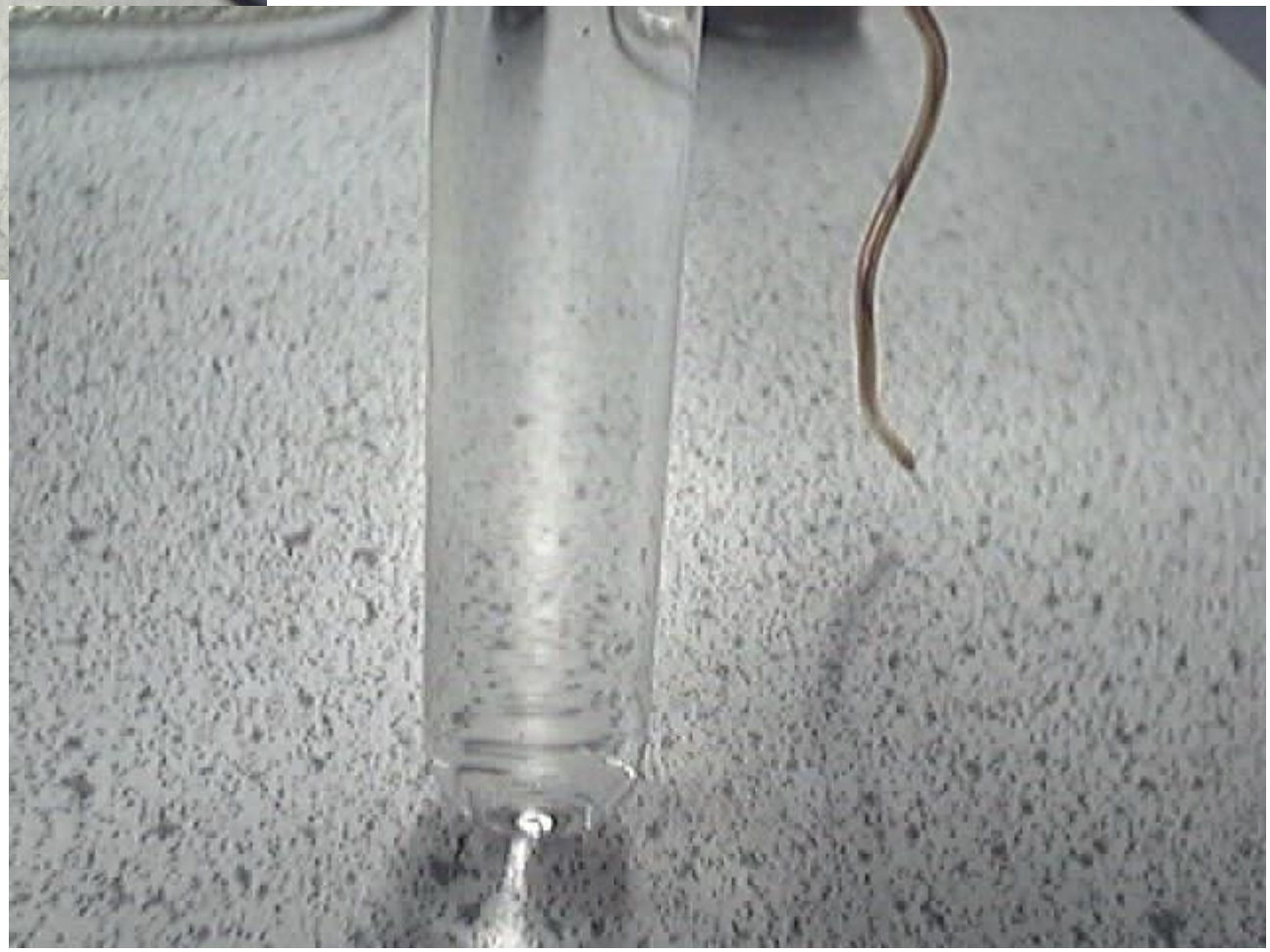
Electrolysis

carbon

Heat with carbon



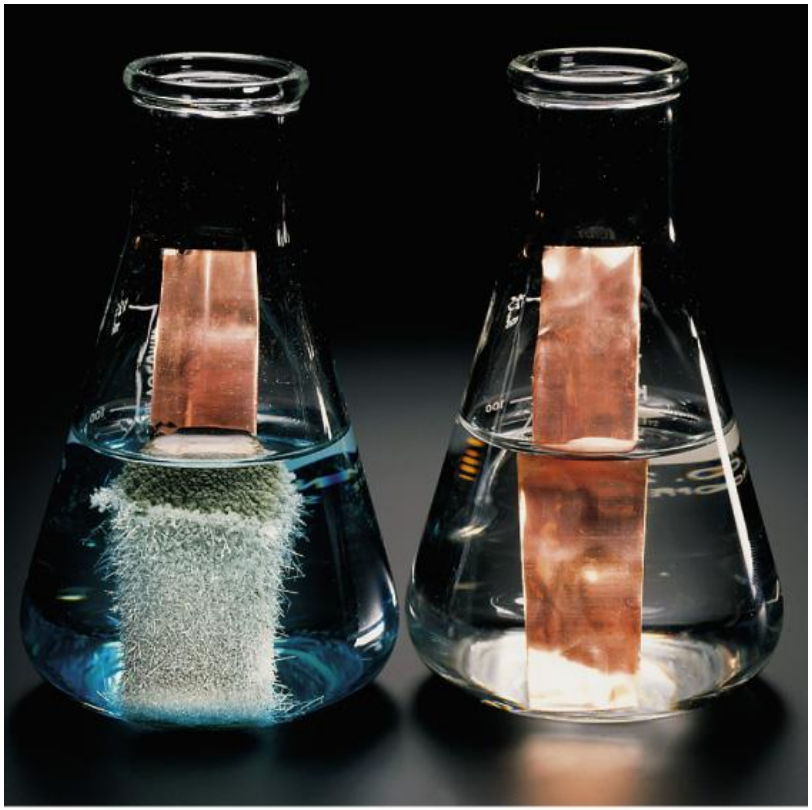
Copper wire is placed in a solution of silver nitrate…..



Explain what happens?

Displacement reactions

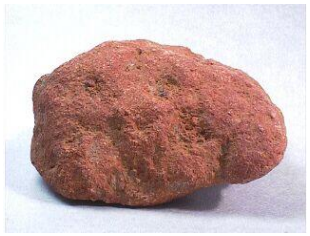
This is a reaction in which a more reactive element pushes out a least reactive element from a compound.



(a) (b)

copper + silver nitrate → copper nitrate + silver

Extracting metals



Metals are usually found in the ground in compounds. These compounds may be mixed with other substances. This mixture is called an ORE. For example, iron is found in the ore Haematite which is rich in the compound iron oxide. Aluminium is found as aluminium oxide in the ore called Bauxite.

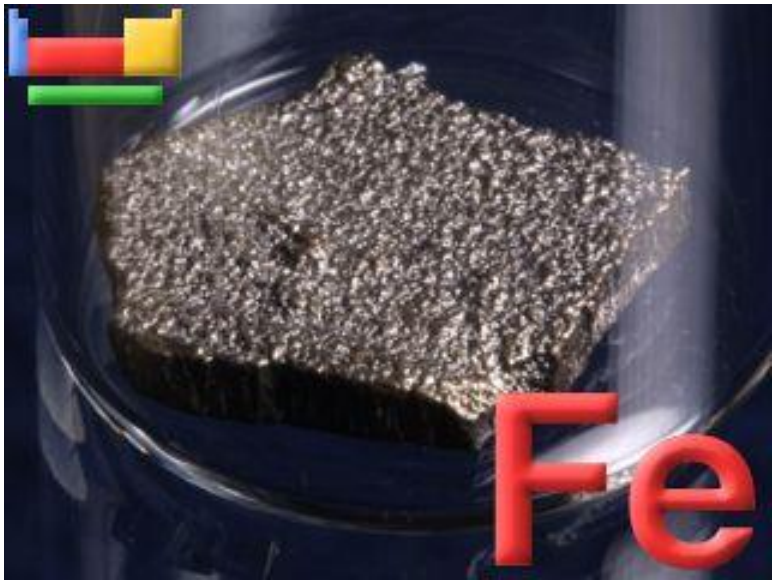
The method used to extract the metal from the ore depends on how reactive it is.

Reduction by heating with carbon

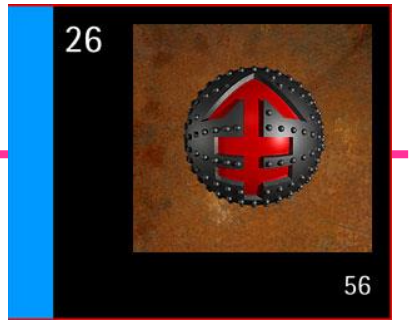
Electrolysis

Lesson 3

Iron



Iron – the facts



Discovered : known to ancient civilisations

Origin : The name comes from the Anglo-Saxon ‘iren’, and the symbol from the Latin ‘ferrum’, meaning iron.

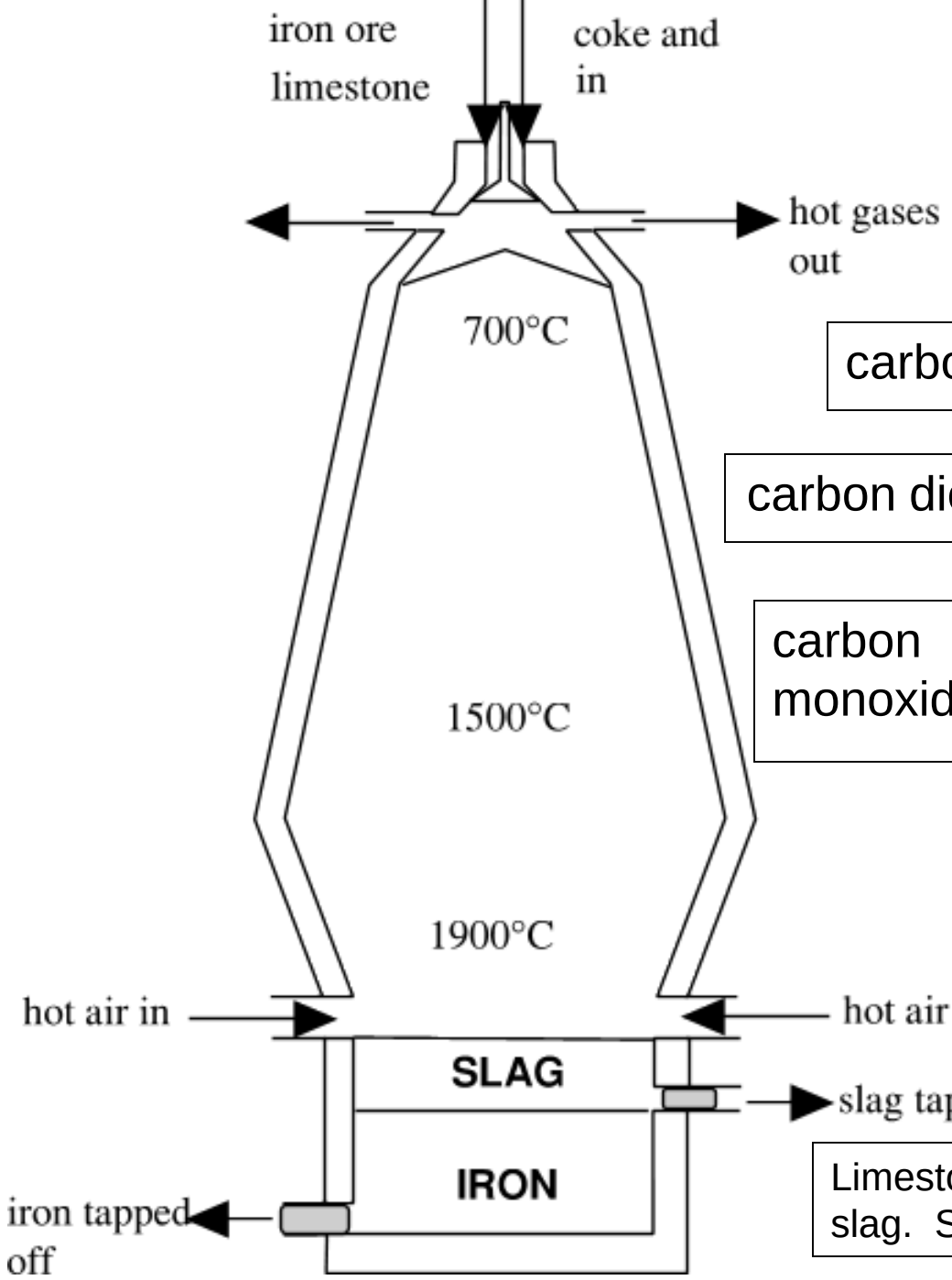
- Iron is an enigma - it rusts easily and yet is the most important of all metals; world production exceeds 700 million tonnes a year.

- **Small amounts of carbon is added to iron to produce steel** and when chromium is added to this, the result is non-corroding stainless steel (small amounts of nickel may also be added). Iron is also an essential element for all forms of life.

Extracting Iron

Haematite is the ore which contains lots of the compound iron oxide.

To extract iron from the compound, it is heated in a furnace with carbon. The carbon removes the oxygen from the iron oxide to leave just iron. The removal of oxygen from a compound is called REDUCTION. [The gain of oxygen is called OXIDATION].



This reaction produces lots of heat

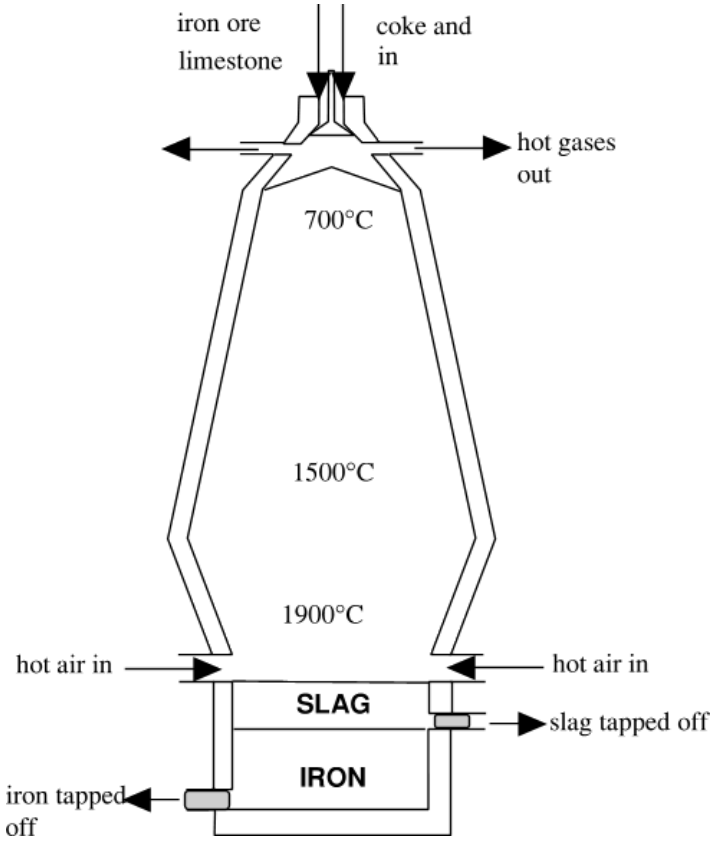
carbon + oxygen → carbon dioxide

carbon dioxide + carbon → carbon monoxide

carbon monoxide + iron oxide → iron + carbon dioxide

Limestone removes sandy impurities to form slag. Slag is used in road building.

The reactions



1. Blasts of hot air (oxygen) oxidise coke (carbon) to carbon dioxide.

$C + O_2 \rightarrow CO_2$ at 1500 °C.
exothermic reaction

2. The carbon dioxide reacts with more carbon to produce carbon monoxide.

$CO_2 + C \rightarrow CO$ at 800 °C.

3. The carbon monoxide reduces the iron oxide to iron.

$Fe_2O_3 + CO \rightarrow Fe + CO_2$ at 700 °C.

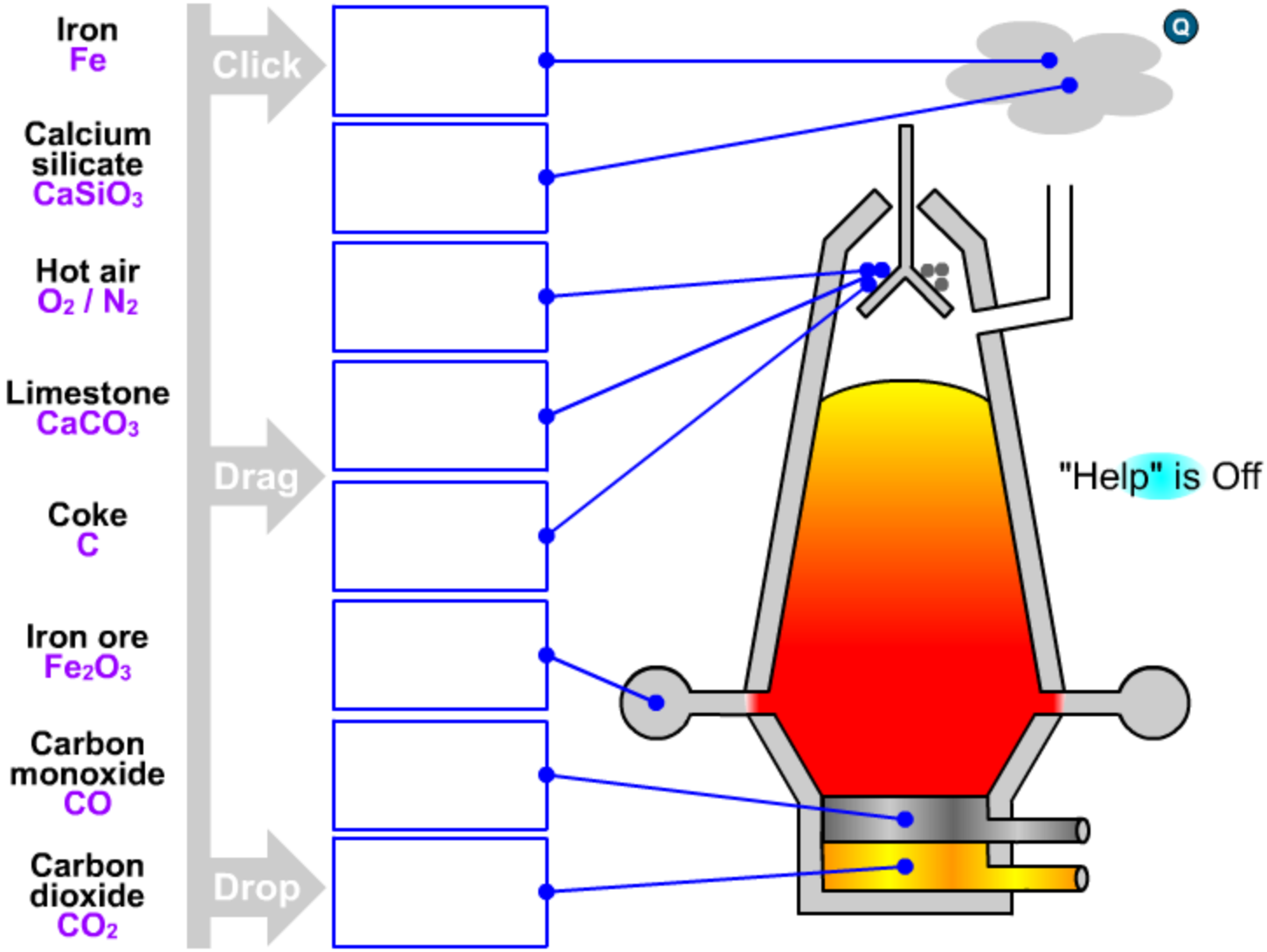
4. The heat in the furnace causes the thermal decomposition of limestone (calcium carbonate):

$CaCO_3 \rightarrow CO_2 + CaO$ at 1000 °C
endothermic reaction

5. The calcium oxide (CaO) reacts with impurities such as sand (silicon dioxide) to form calcium silicate.

$CaO + SiO_2 \rightarrow CaSiO_3$ (slag)
alkali acidic

The blast furnace



Making iron useful

The iron produced by the blast furnace is not very useful because it contains lots of carbon (4%) which makes it brittle.

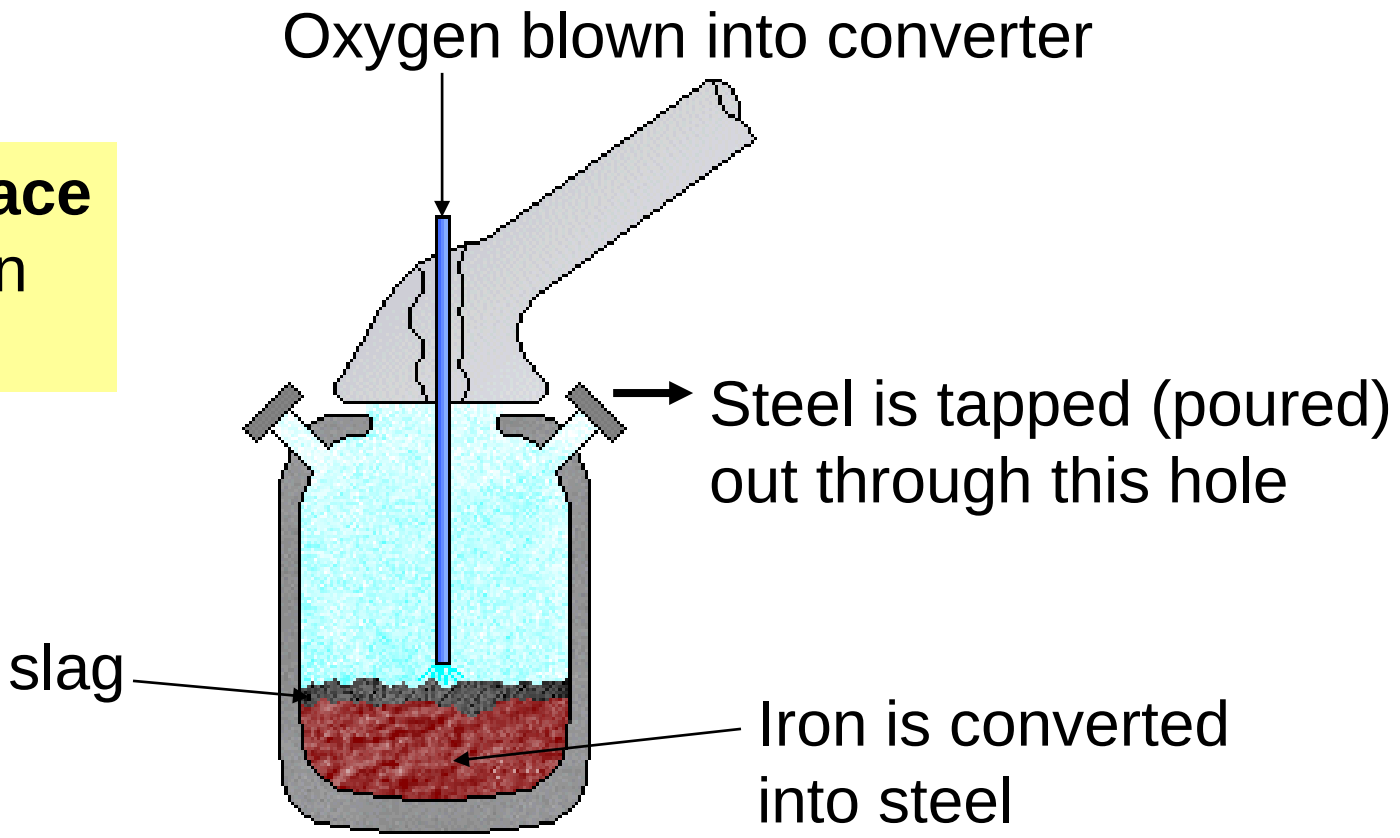
But, if the carbon and impurities are removed then the iron becomes too soft.

What do you do then????

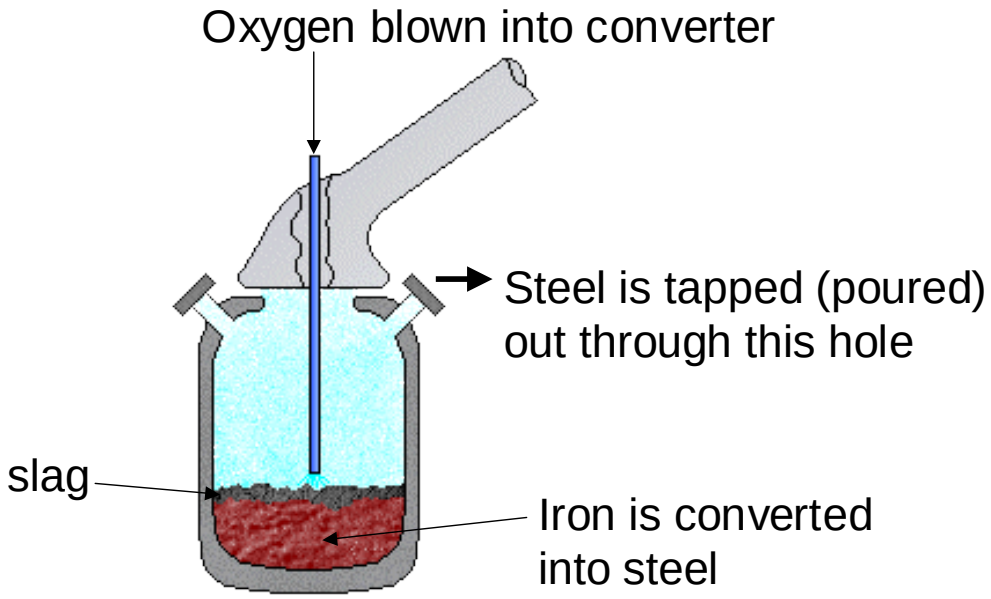
Making steel from iron

To make iron more useful as a strong and tough material it is converted to steel.

Oxygen furnace – converts iron into steel



Making steel from iron



Molten iron from the blast furnace is poured into the oxygen furnace. Oxygen is blown into the furnace under high pressure.

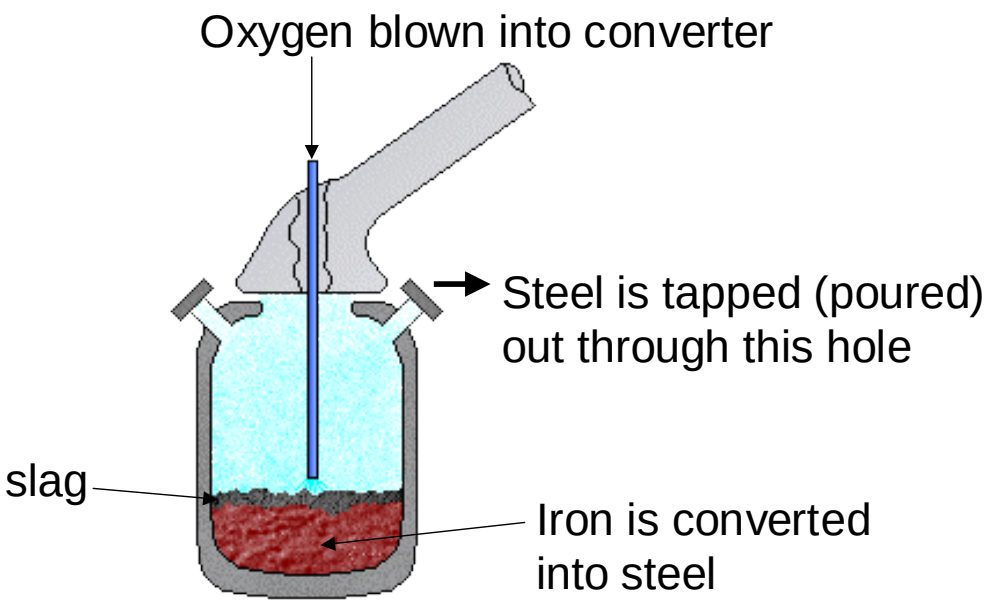
The oxygen oxidises some of the carbon to carbon monoxide.

$$2C + O_2 \rightarrow 2CO$$

The carbon monoxide reacts with more oxygen to produce carbon dioxide.

$$2CO + O_2 \rightarrow 2CO_2$$

Making steel from iron



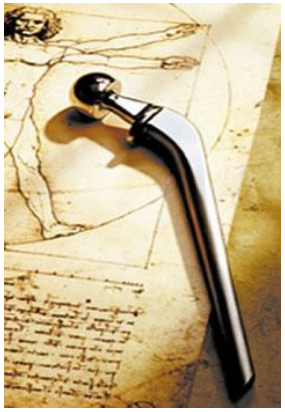
The process lowers the carbon content from 4 % to 2 %. One product is **mild steel** which contains between 0.1 % and 0.4 % carbon.

The properties of steel can be further improved by adding other metals (e.g., chromium, nickel, titanium and manganese) to it to turn it into alloys.

Steel alloys

Steel + chromium + nickel = **stainless steel**

Steel + titanium = **titanium steel**



Steel + manganese = **manganese steel**

H_2SO_4

Lesson 4

Sulfuric acid

Uses of sulfuric acid

Fertilisers
(e.g., ammonium sulphate)

Detergents

Fact! The richer the country, the more sulfuric acid it uses.

Dyes

Plastics

Fibres e.g., rayon

Paints and pigments

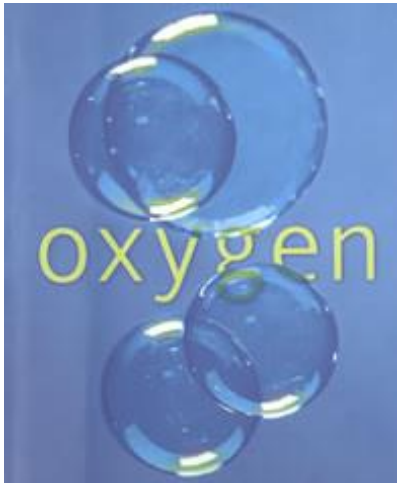
Soaps

Making sulfuric acid - ingredients

Sulfur

Yellow powder

Sulfur can be obtained from its ores: iron pyrites (Iron sulphide, FeS_2), galena (lead sulphide, PbS) and zinc blend (Zinc sulphide, ZnS).



Oxygen gas

From the air

Add some heat…

STEP 1

Sulfur + Oxygen → sulfur dioxide

$S + O_2 \rightarrow SO_2$

Alternatively, the ore is burned in oxygen to produce SO_2

The production of sulfuric acid is called the Contact Process

More oxygen, heat and catalyst

STEP 2

Excess air, heat (420 ^{o}C) and a vanadium (V) oxide catalyst turns sulfur dioxide into sulfur trioxide.

Sulfur dioxide + Oxygen $\rightleftharpoons$ sulfur trioxide

$SO_2 + O_2 \rightleftharpoons SO_3$

The reaction is exothermic (produces heat). And since it is reversible, it is important that the reaction does not over heat or else the sulfur trioxide will turn back into sulfur dioxide.

This sign shows that the reaction is reversible.

Conversion to sulfuric acid

STEP 3 The sulfur trioxide is added to concentrated sulfuric acid to form a very concentrated substance called Oleum.

Sulfur trioxide + sulfuric acid → Oleum

$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$

STEP 4 The oleum is added to water to form concentrated sulfuric acid.

Oleum + water → sulfuric acid

$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

Safety first

The sulfur trioxide could be added to water to produce sulfuric acid but the reaction is too violent and dangerous.

Lesson 5

Organic chemistry

What is an organic compound?

An **organic compound** is one that contains the elements carbon and hydrogen. Other elements may also be present such as oxygen and nitrogen.

There is a vast number of organic compounds. The reason for this is that carbon atoms can bond together to produce chains.

Groups of organic compounds

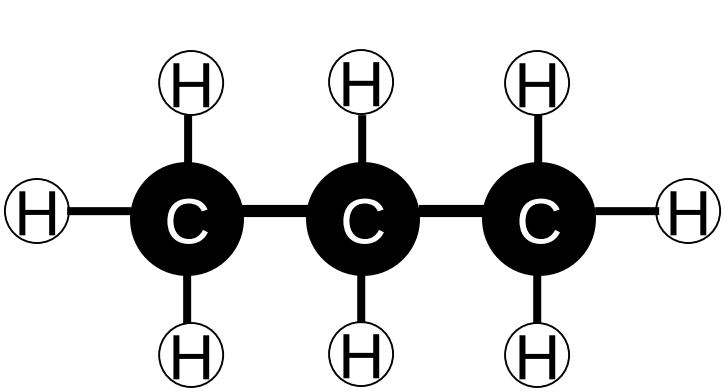
Organic compounds can be grouped into families called **homologous series**.

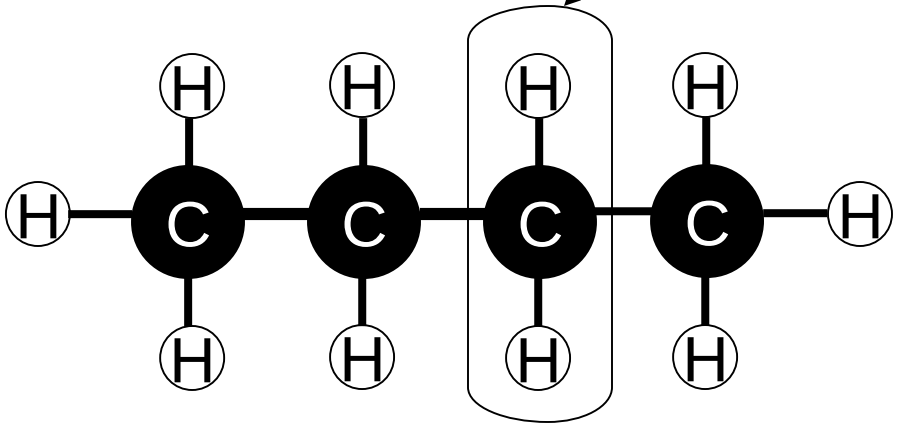
(same)

The compounds in a homologous series:

- are called homologues.
- have the same general formula.
- have increasing numbers of carbon atoms.

The molecules increase by 1 carbon and 2 hydrogen atoms

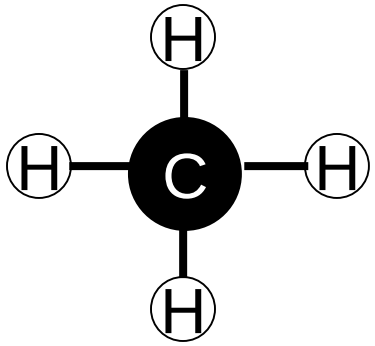




Homologous series of alkanes

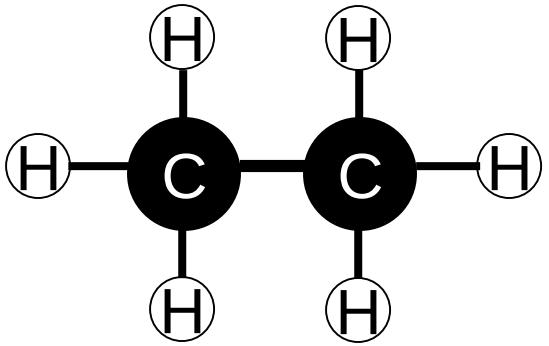
CH_4

methane



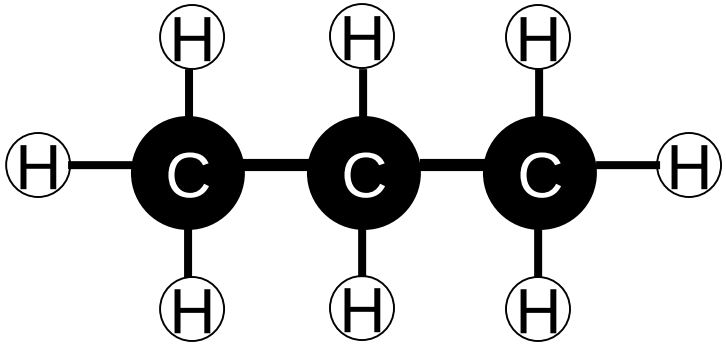
C_2H_6

ethane



C_3H_8

propane



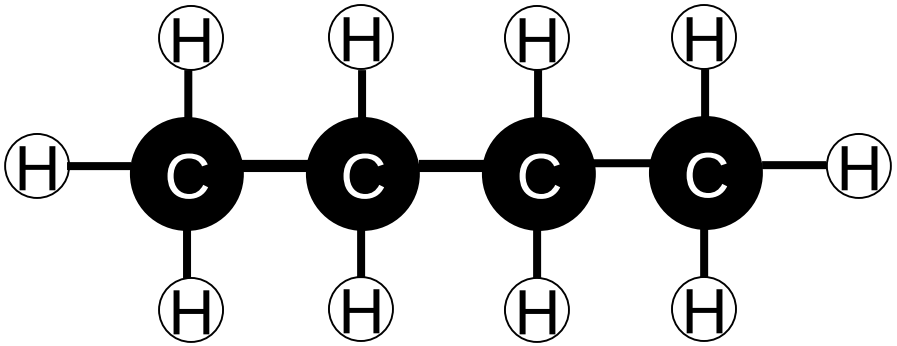
-ane

General formula

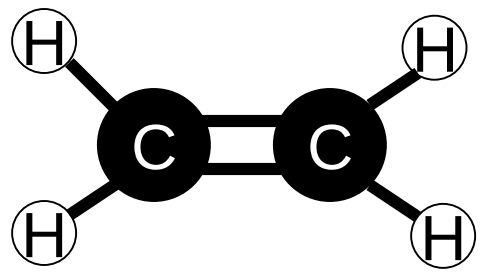
C_nH_{2n+2}

C_4H_{10}

butane

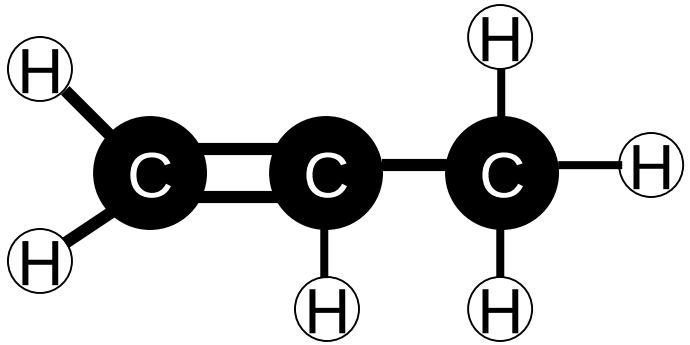


Homologous series of alkenes



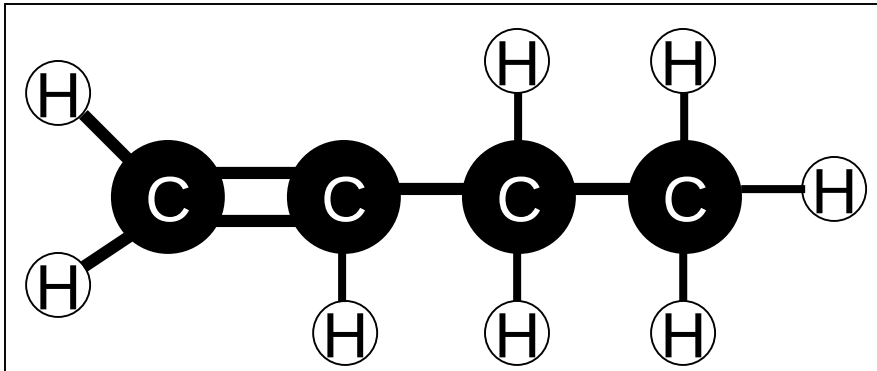
C_2H_4

ethene



C_3H_6

propene

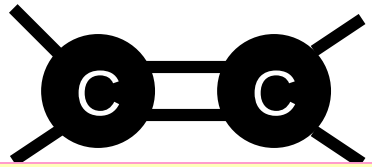


C_4H_8

butene

General formula

C_nH_{2n}

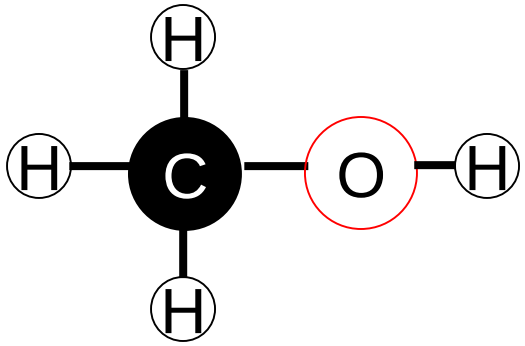


Double bond is the functional group

-ene

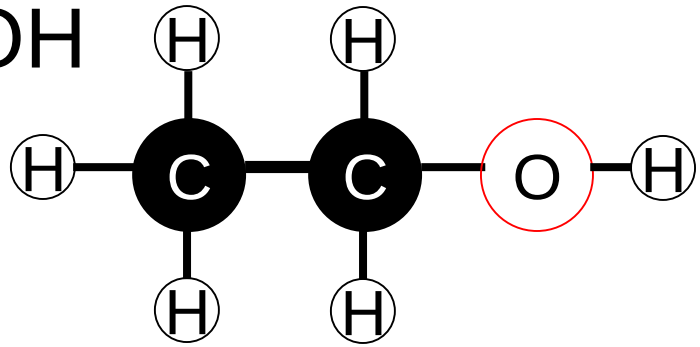
Homologous series of alcohols

CH_3OH



methanol

C_2H_5OH

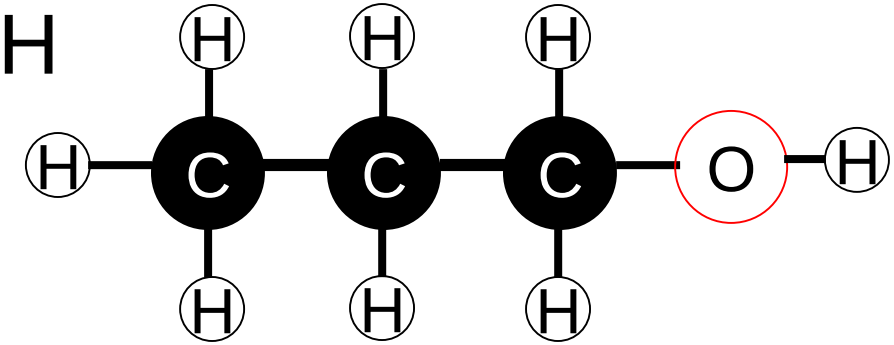


ethanol

General formula

$C_nH_{2n+1}OH$

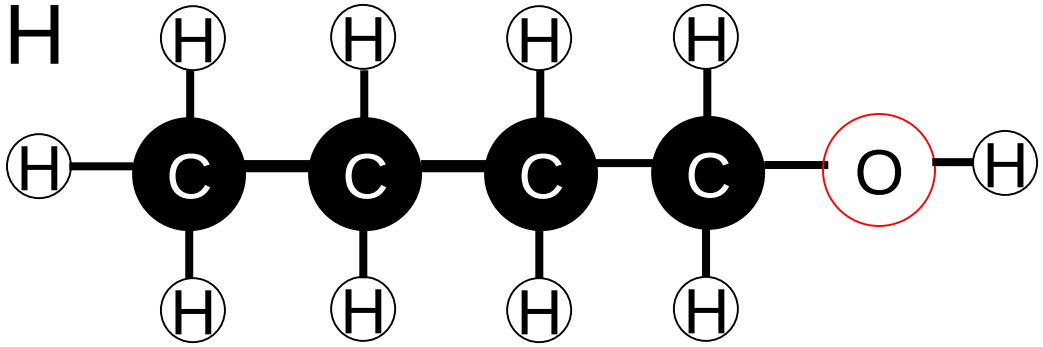
C_3H_7OH



propanol

-anol

C_4H_9OH



butanol

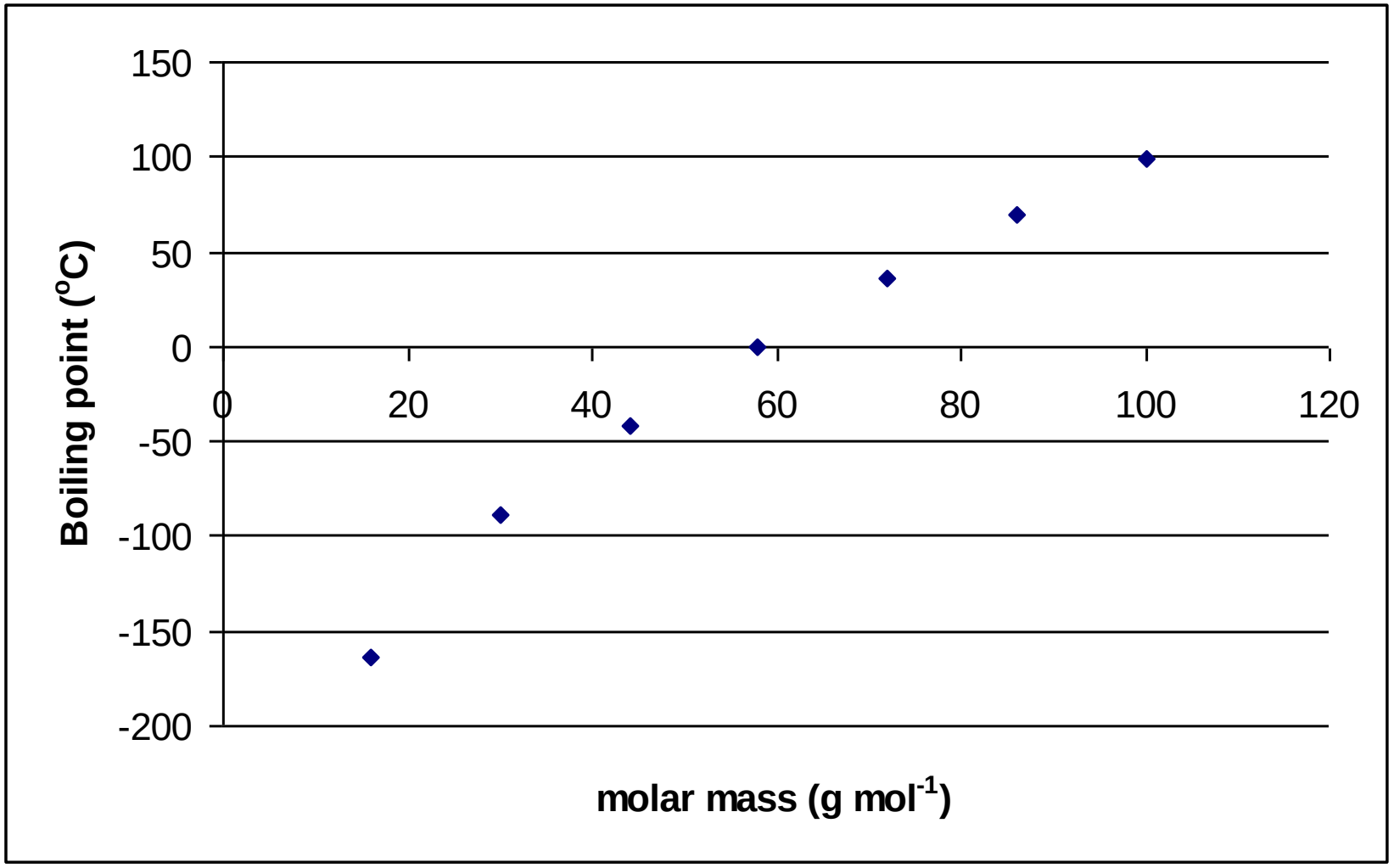
Properties of a homologous series

Physical properties

There is a gradual trend in the melting and boiling points of the members in a homologous series.

Member	Formula	Molar mass	Boiling Point oC
Methane	CH_4	16	-163.9
Ethane	C_2H_6	30	-88.5
Propane	C_3H_8	44	-42
Butane	C_4H_{10}	58	-0.4
Pentane	C_5H_{12}	72	36
Hexane	C_6H_{14}	86	69.1
Heptane	C_7H_{16}	100	98.5

Boiling points of the alkanes



The boiling point increases as molecule gets bigger.

More physical properties

As the number of carbon atoms increase in a molecule:

1. The melting point (mp) and boiling point (bp) increases.
2. The increase in mp and bp means that the smaller molecules are gases, and as they get bigger they become thicker and thicker liquids. Very large molecules are solids at room temperature.
3. The larger the molecule the more difficult is becomes to burn since it takes more energy to turn it into a vapour before it can burn.
4. Larger molecules burn with a yellow, sooty flame.

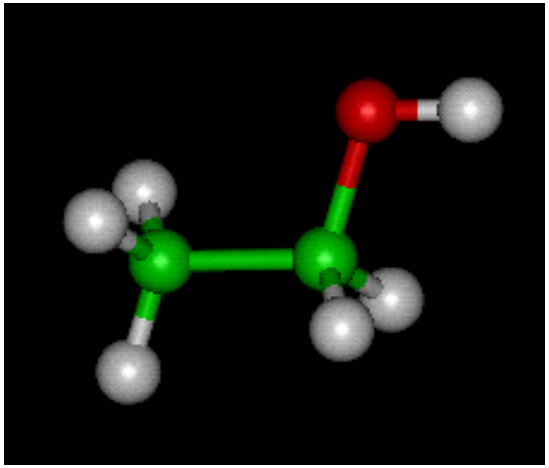
Properties of a homologous series

Chemical properties

Compounds in a homologous series also react in a similar way., e.g., alkanes burn in oxygen to form carbon dioxide and water.

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

ethane

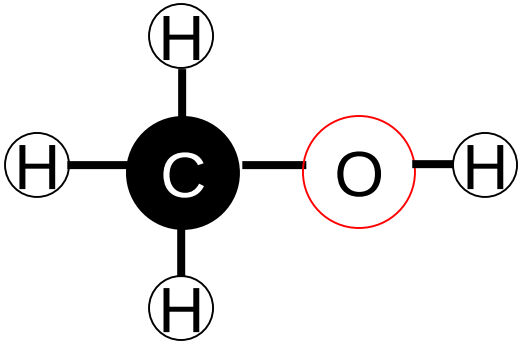


Lesson 6

Alcohols

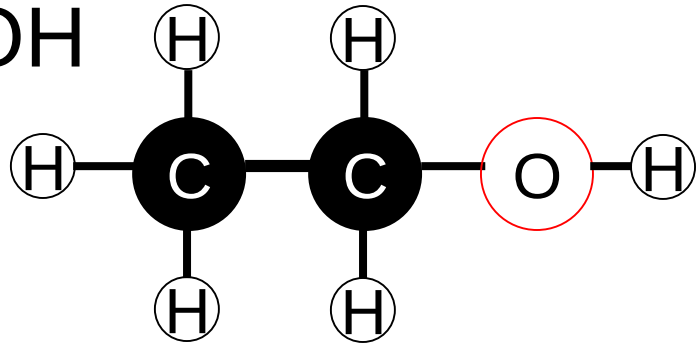
Homologous series of alcohols

CH_3OH



methanol

C_2H_5OH

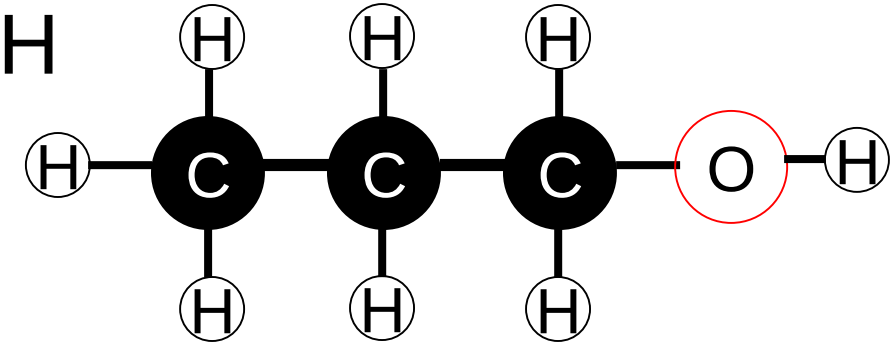


ethanol

General formula

$C_nH_{2n+1}OH$

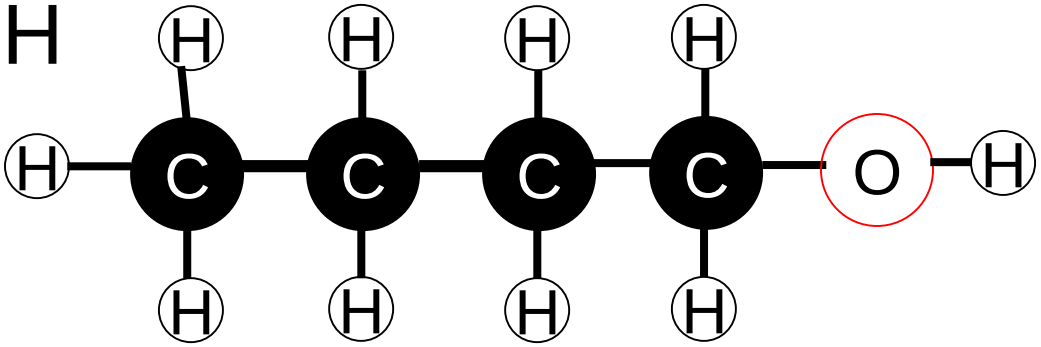
C_3H_7OH



propanol

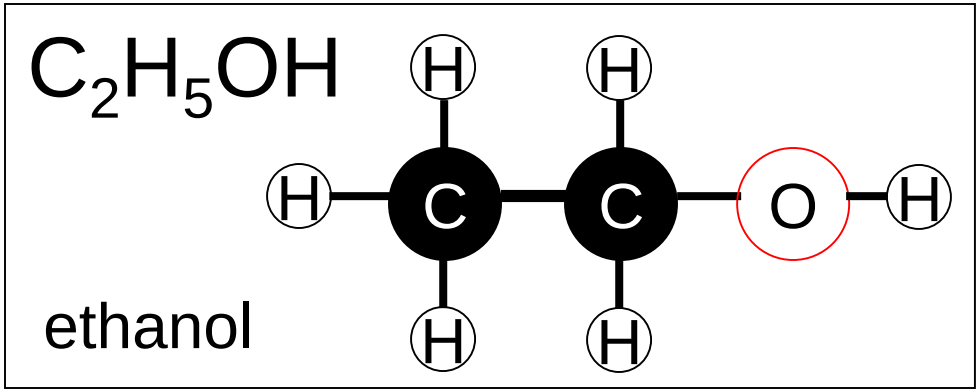
-anol

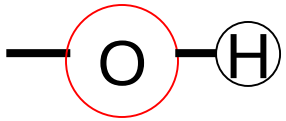
C_4H_9OH



butanol

Ethanol – an alcohol



The functional group in alcohols is  or –OH.

Ethanol is one of many alcohols. It is a liquid at room temperature and it is readily miscible (soluble) in water.

However, as the alcohol gets bigger, melting and boiling points increase and they become less and less soluble in water.

Solvent

Dissolves other chemicals

Alcoholic drinks

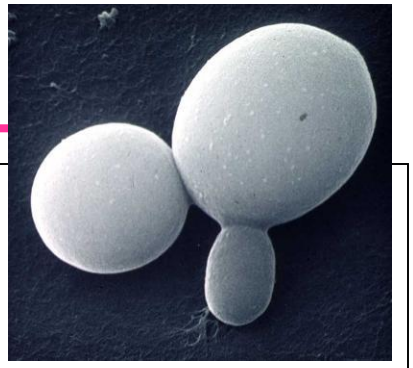
Uses of Ethanol

Fuel

Industrial methylated spirits

e.g., for cleaning paint brushes

How is ethanol made?



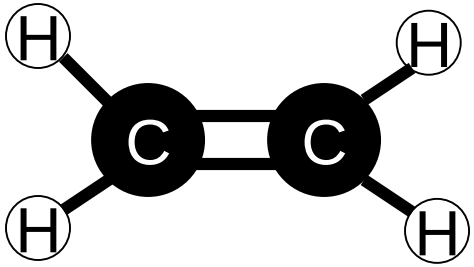
Yeast fermentation

glucose → Ethanol + carbon dioxide + Energy

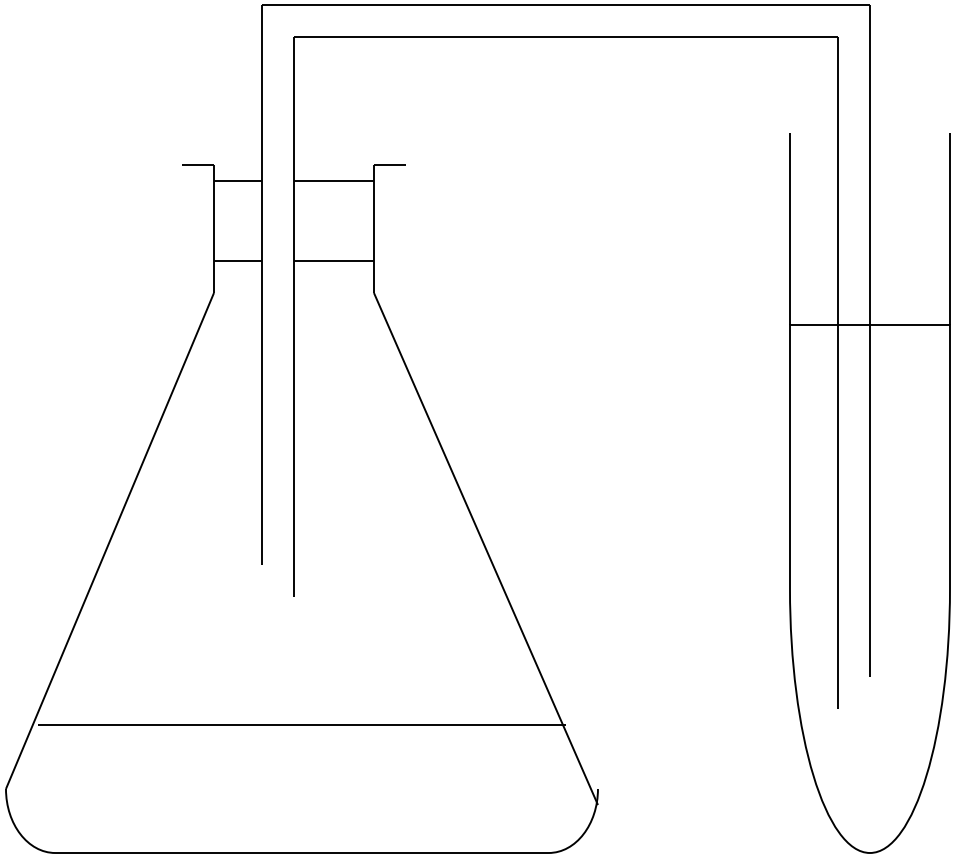
Enzymes in yeast

$C_6H_{12}O_{6\ (aq)} \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow 2C_2H_5OH_{\ (aq)} + 2CO_{2\ (g)} + 112\ KJ$

Hydration of ethene



Fermentation

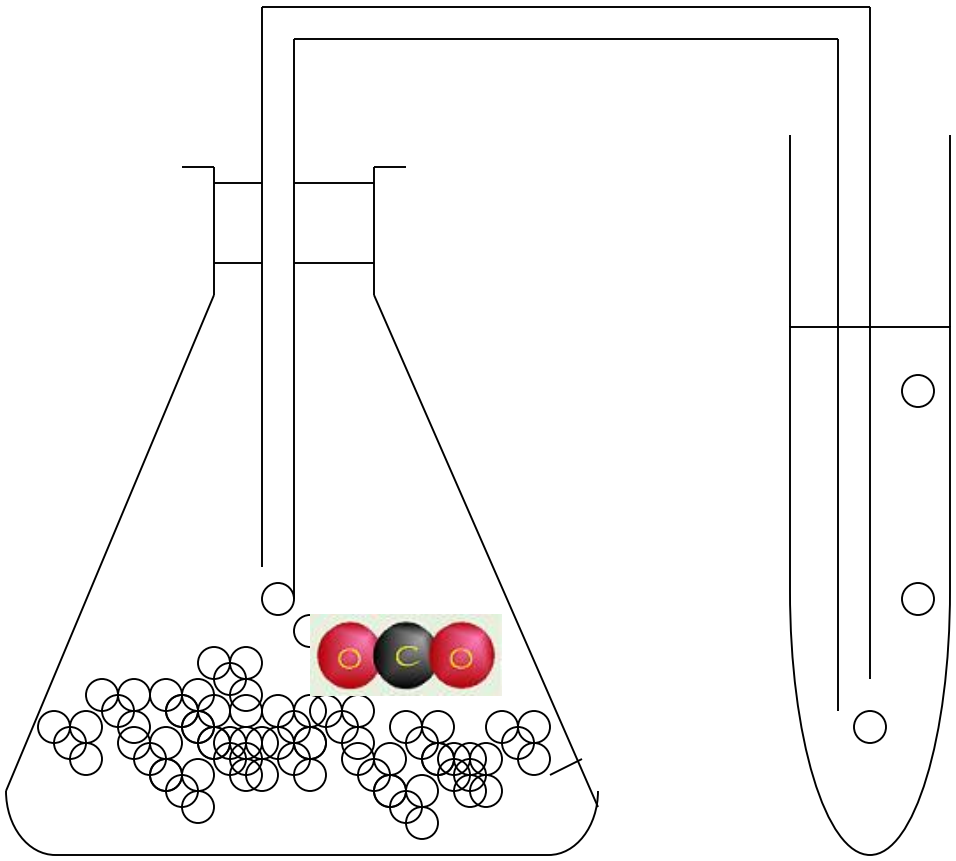


limewater

Colourless

Add yeast + water + sugar

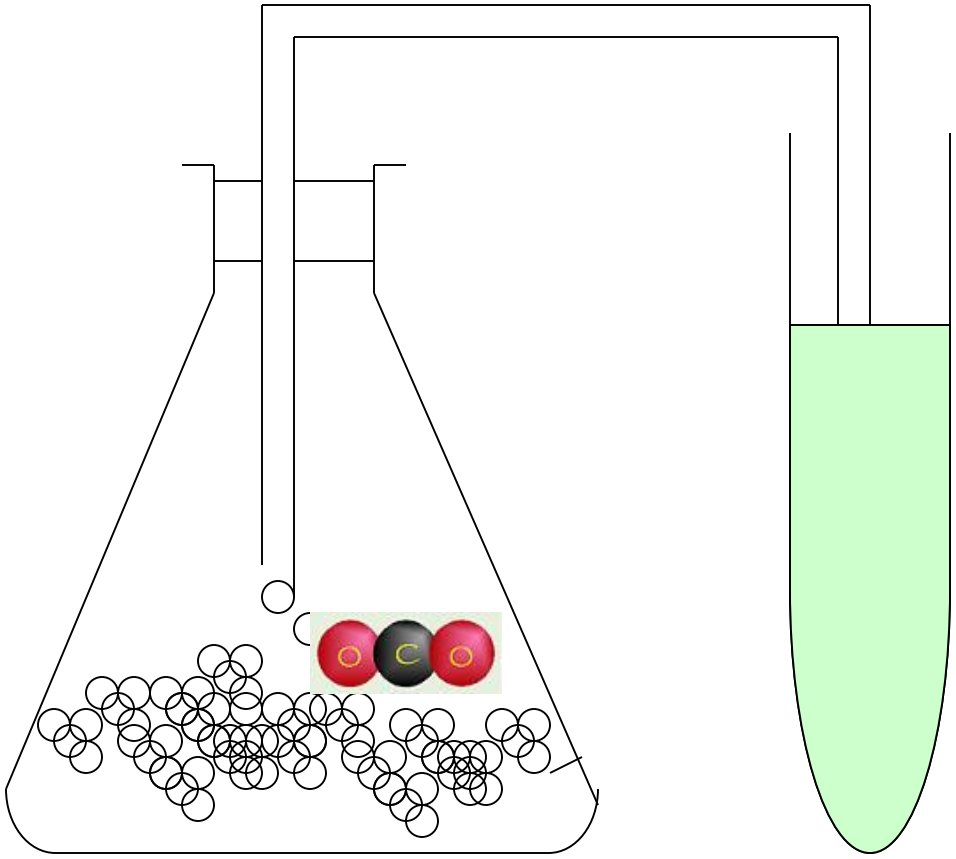
Fermentation



Fermentation

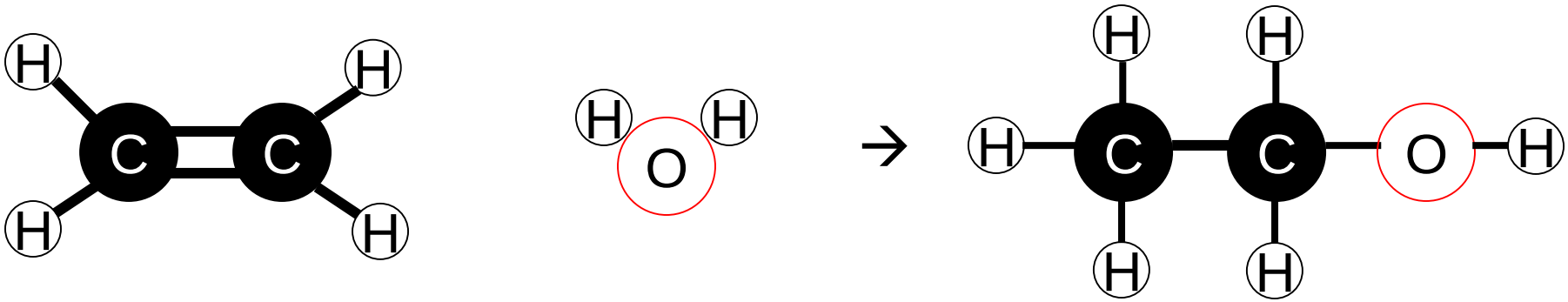
limewater

Fermentation



limewater turns milky

Hydration of ethene



Ethene + water (steam) → ethanol

C_2H_4 + H_2O → C_2H_5OH

Reaction conditions:

300 ^oC

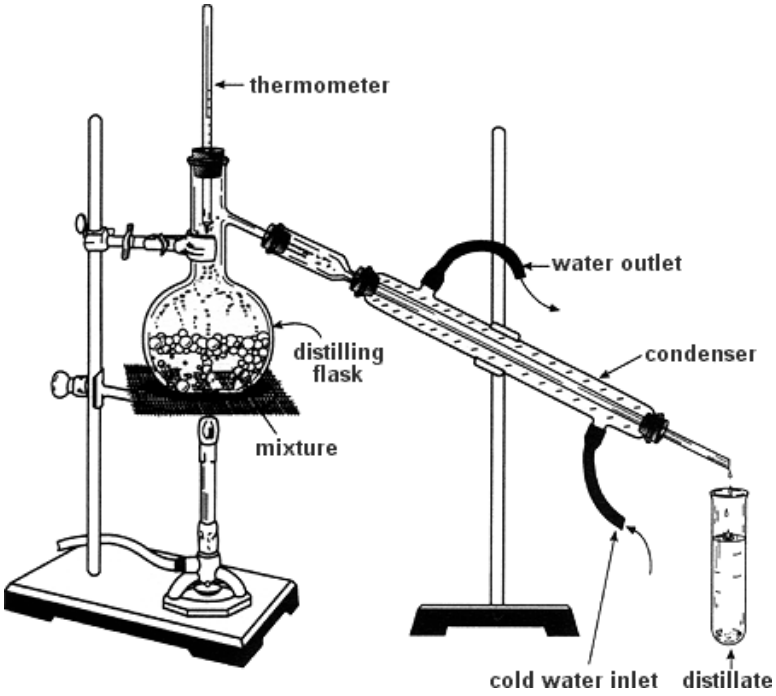
Phosphoric acid catalyst

High pressure (60-70 atm)

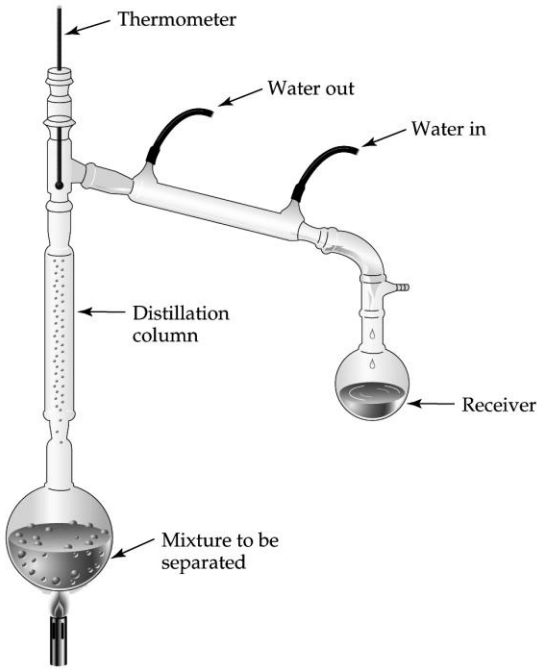
Fermentation versus hydration

Fermentation using yeast	Hydration of ethene
Uses natural raw materials (e.g., yeast, sugar cane)	Uses crude oil (ethene is made by cracking)
Slow reaction. Cannot make lots of ethanol	Fast reaction. Lots of ethanol can be produced
Ethanol is not pure	Ethanol has a high purity
Used to make alcohol for alcoholic drinks	Alcohol used for industrial processes

Purifying alcohols – Fractional distillation



Distillation



Fractional distillation

Distillation and fractional distillation are used to separate mixtures of liquids because they have different boiling points.

Distillation – a mixture of 2 liquids (cannot separate <u>miscible</u> liquids such as water and alcohol).
Fractional distillation – a mixture of more than 2 liquids.

Industrial methylated spirits

Fractional distillation can be used to produce ethanol to a purity of 96%. This would be highly toxic.

To make it unfit to drink, methanol is added to make it taste horrible. A purple dye is also added to make it less attractive to drink.

Uses of IMS/industrial ethanol

Fuel, solvent for cleaning paint brushes and varnishes, make cosmetics, make ethanoic acid, make ethyl ethanoate.

Alcoholic drinks

Disadvantages

Slow reactions
Liver and brain damage
Become aggressive and depressed

1 unit =
½ pint of
beer

Advantages

Makes you relaxed
Small amount prevents heart problems (red wine or grape juice).

Lesson 7

Reactions of the alcohols

Combustion

They burn to form CO_2 and H_2O and energy.

Reactions of the alcohols

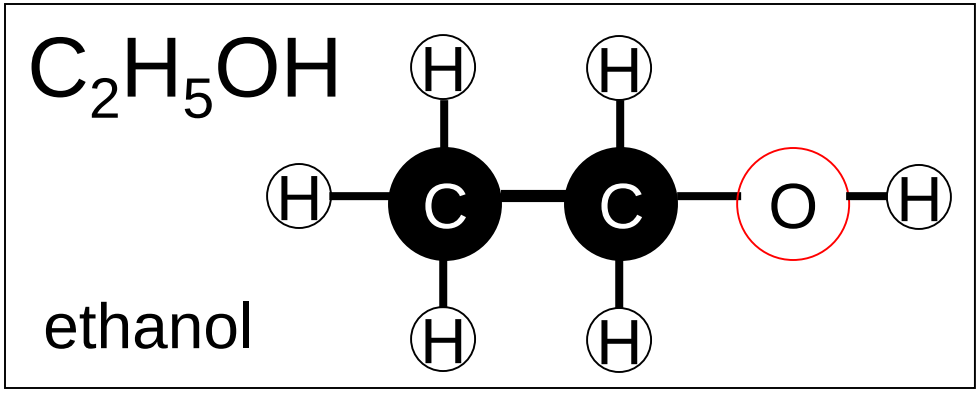
Oxidation

Alcohols can be oxidised into carboxylic acids.

The reaction is done under **reflux** conditions

Burning alcohols

The alcohols are part of a homologous series – they all have a hydrocarbon chain with an –OH functional group., e.g.,



All alcohols burn in oxygen to produce carbon dioxide and water.

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

ethanol

Burning alcohols

You will investigate the burning of 3 different alcohols:

Methanol
Propanol (propan-1-ol)
Hexanol (hexan-1-ol)

You will add 50 cm^3 of water to the metal can and measure its temperature.

Then you will light the wick of the burner and place the burner under the can. Start the stopwatch and time how long it takes for the water to heat up by 20 ^oC.

Burning alcohols

Burning alcohols

	Time taken to heat the water by 20 ^{o}C, in seconds
Methanol	
Propanol	
Hexanol	

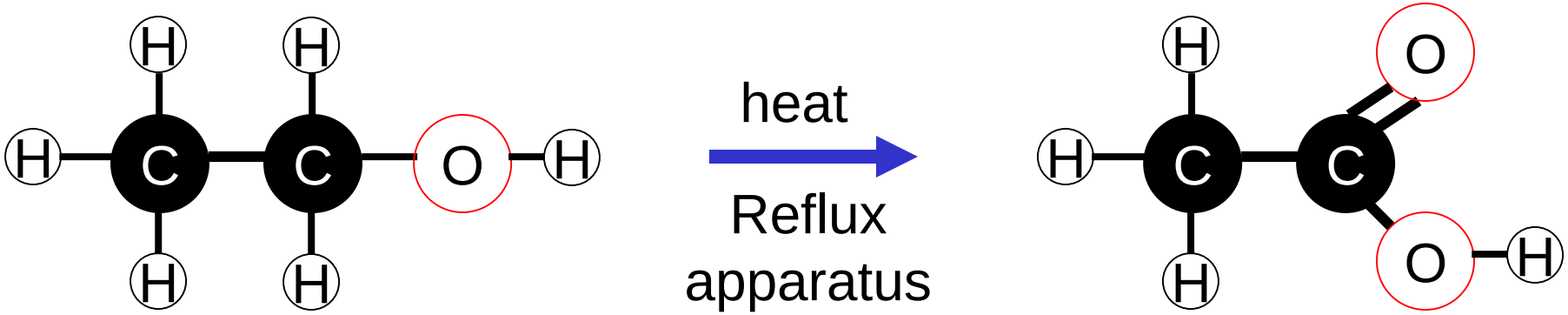
The larger the alcohol, the more heat energy produced. This would mean the water would heat up faster.

Record, the colour of the flame, and if any soot (carbon) is formed. Write down any other suitable observation.

Oxidation of alcohols

Oxidation reactions usually involve a compound gaining oxygen.

Alcohols can be oxidised into a carboxylic acid. Vinegar is a carboxylic acid called ethanoic acid.



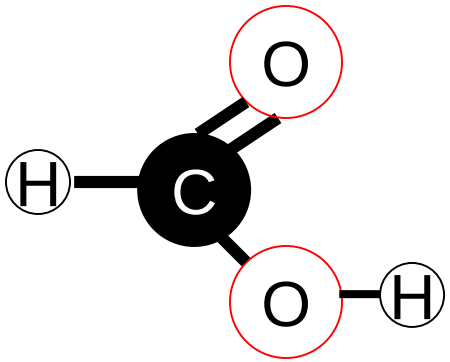
An oxidising agent is also added to the reaction. This compound provides the extra oxygen needed to make the carboxylic acid. In this case **Potassium dichromate** is the oxidising agent.

Oxidation of alcohols [Higher only]

$$C_2H_5OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$$

Oxidation also involves the loss of electrons and/or hydrogen

Homologous series of carboxylic acids

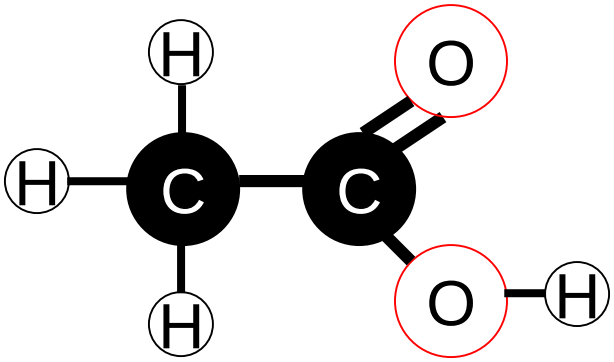


HCOOH
Methanoic acid

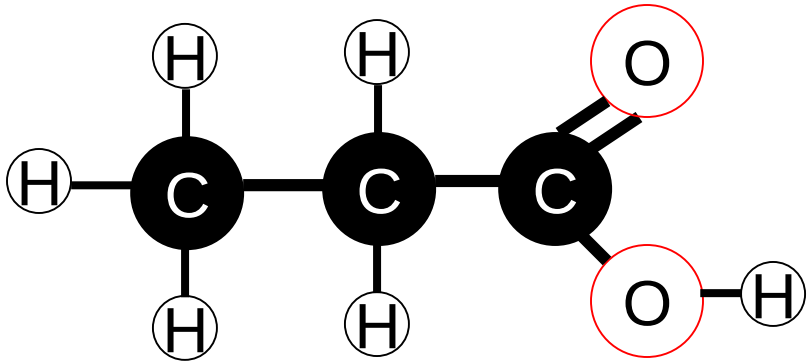
General formula

$$C_nH_{2n+1}COOH$$

-oic acid

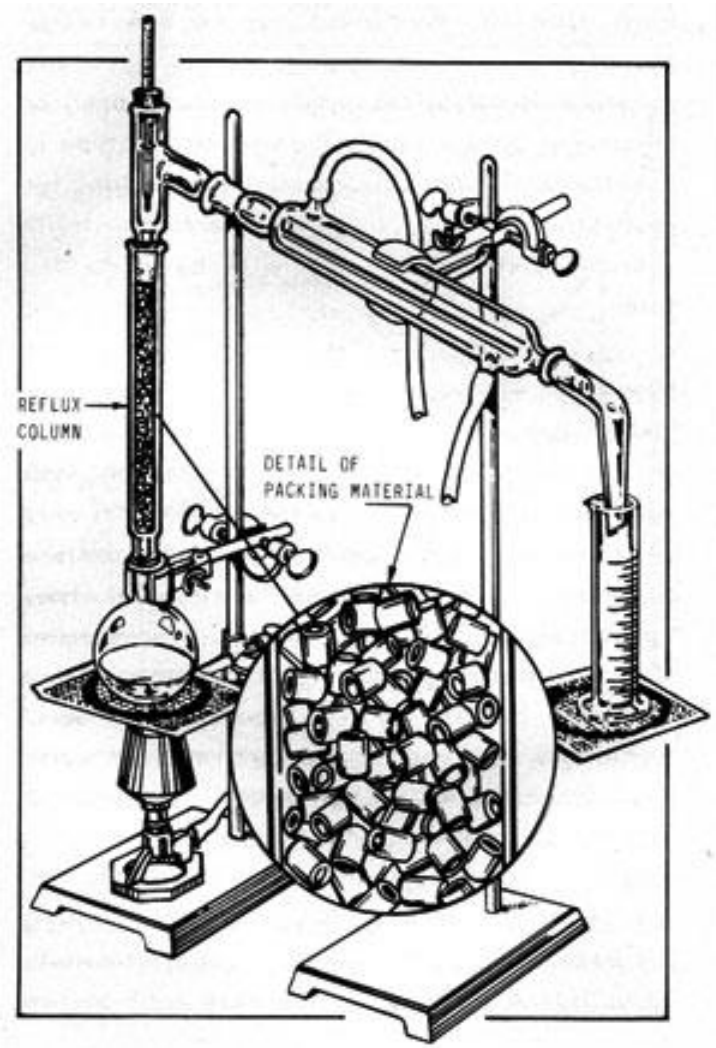


CH_3COOH
Ethanoic acid



C_2H_5COOH
Propanoic acid

Reflux



‘reaction is done under reflux’

In organic chemistry many of the chemicals have low boiling points. Therefore, if heat is required to make a reaction work then it is very likely that the reactants will evaporate before they have even had a chance to react. To stop this happening a reflux column is used which has a large internal surface area and is usually cooled like a condenser. **This allows the reactants to condense and drop back into the reaction flask so that they can react**.

Properties of ethanoic acid (vinegar)

Ethanoic acid……

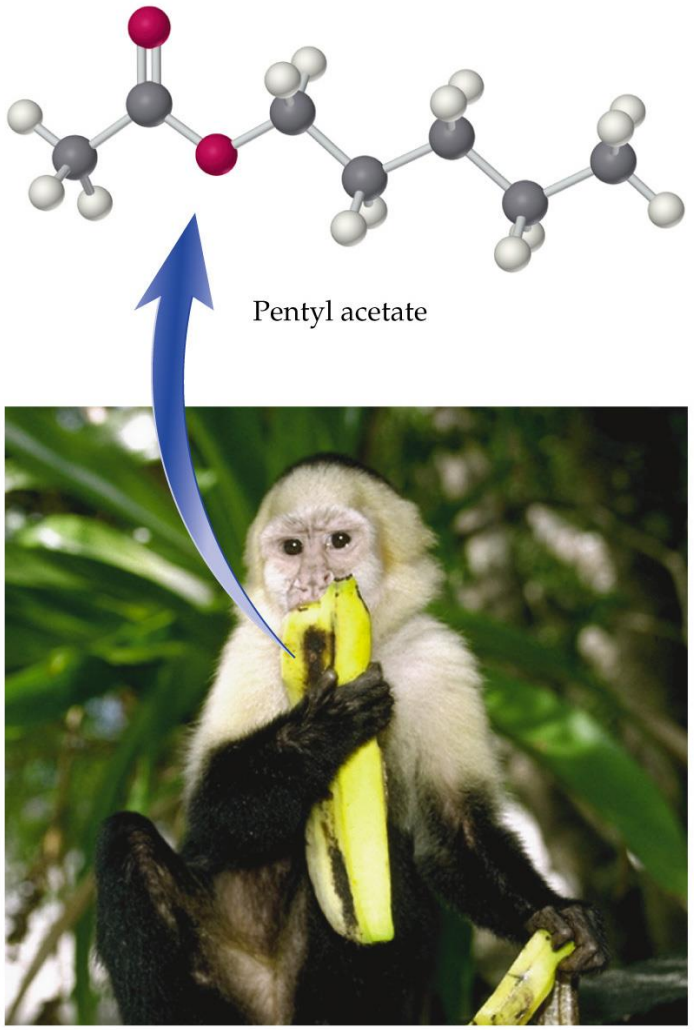
- Its acidic – turns blue litmus red.
- Reacts with metals, carbonates and hydroxides like any other acid. The salt formed is called an ethanoate.

You should be able to write word equations to describe each of the above reactions.

Metal + ethanoic acid → metal ethanoate + hydrogen gas

Metal carbonate + ethanoic acid → metal ethanoate + water

Metal hydroxide + ethanoic acid → metal ethanoate + water



Lesson 8

Making esters

Making esters

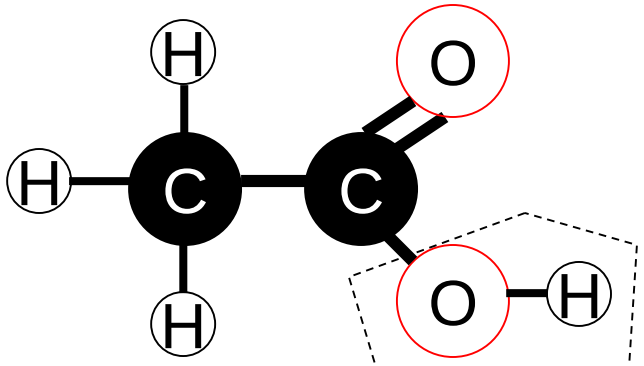
Alcohol + carboxylic acid → ester

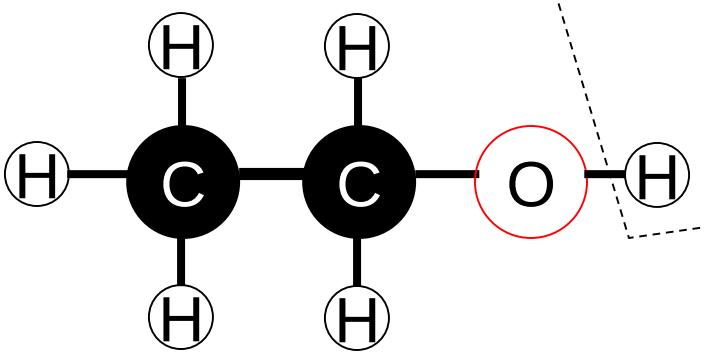
Concentrated sulfuric acid and heat

Esters have pleasant odours. If a reaction produces a pleasant fragrance then it is very likely that you reacted an alcohol with a carboxylic acid.

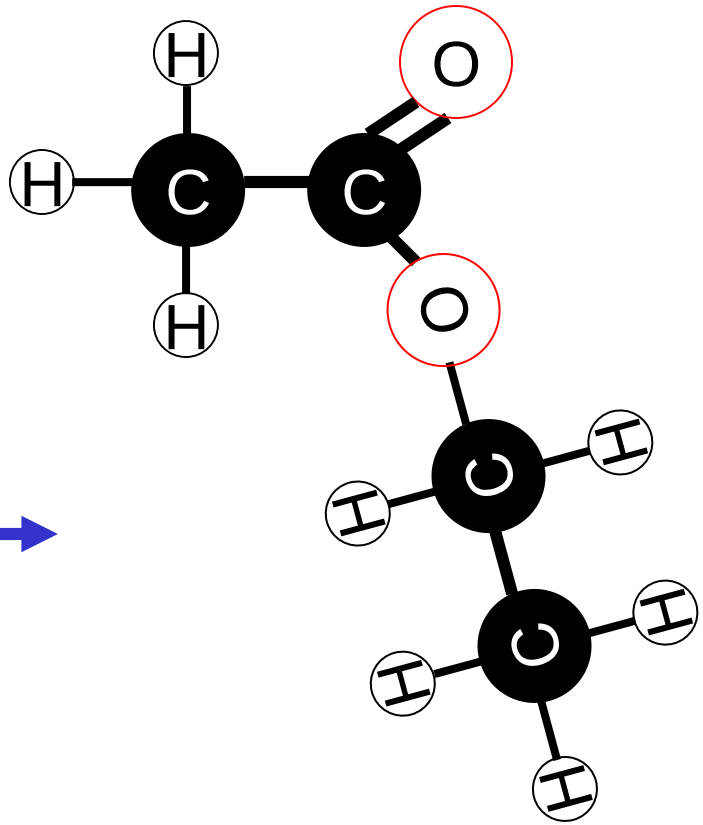
Making ethyl ethanoate (an ester)

Ethanoic acid





Ethanol



H_2O

Ethyl ethanoate

ethanol

Ethanoic acid