3.1 Atoms into ions

- What does a compound contain? Two or more elements that are chemically combined
- Example of mixing? Sand and blue copper sulphate
- Example of reaction? Sodium and chlorine makes sodium chloride (s)
- Sharing electrons type of bonding? Covalent
- Transferring electrons type of bonding? Ionic
- What happens in ionic bonding? Atoms lose or gain electrons to form charged particles called ions. These ions have the electronic structure of a noble gas…
- Metal atoms? Loose electrons and become positive ions
- Non-metal atoms? Gain electrons and become negative ions

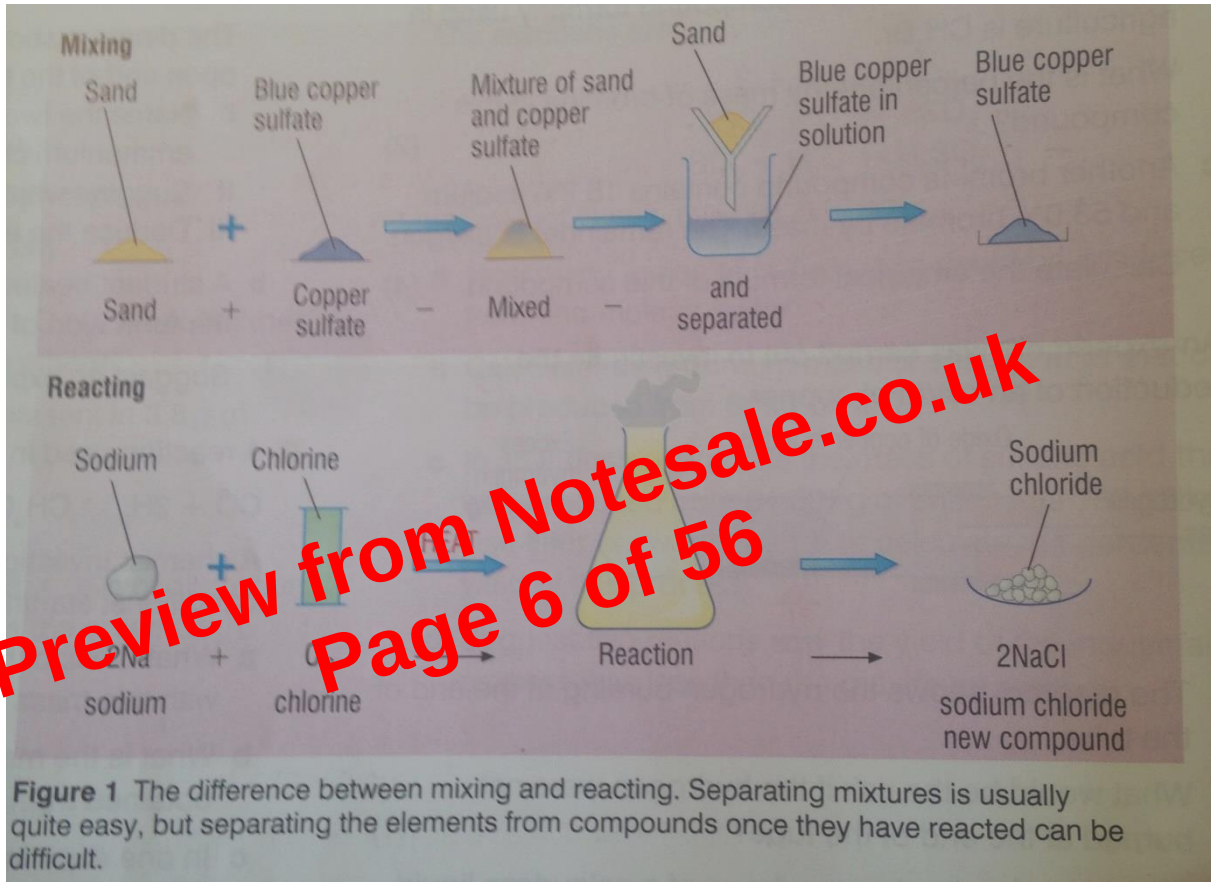

Figure 1 The difference between mixing and reacting. Separating mixtures is usually quite easy, but separating the elements from compounds once they have reacted can be difficult.

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3.2 Ionic bonding

- When are ionic compounds usually formed? When metals react with non-metals
- Ionic bonds? Very strong forces of attraction between the oppositely charged ions
- What is this arrangement called? Giant structure or giant lattice
- When atoms form ionic bonds, atoms from:
    - Group 1 form 1+ ions (loose electrons)
    - Group 2 form 2+ ions (loose electrons)
    - Group 3 form 3+ ions (loose electrons)
    - Group 4 do not form ions (apart from tin and lead)
    - Group 5 form 3- ions (gain electrons)
    - Group 6 form 2- ions (gain electrons)

- With metals lower than carbon in the reactivity series, how can we extract them?
    - We must heat the metal oxide with carbon. The carbon removes the oxygen from the metal oxide to form carbon dioxide
- What is the name for removing oxygen from a compound? Chemical reduction
- How are metals more reactive than carbon extracted from their ores?
    - Electrolysis is used on the molten metal compound

7.4 Extracting copper

Extracting copper from copper-rich ores

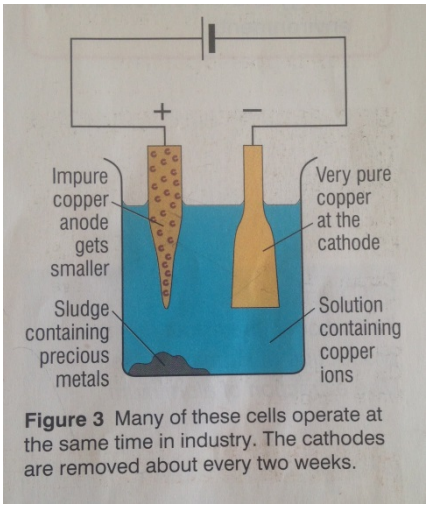

Figure 3 Many of these cells operate at the same time in industry. The cathodes are removed about every two weeks.

- Two main methods to obtain copper metal from ore?
    - Sulfuric acid is used to produce copper sulfate solution, before extracting the metal
    - Smelting involves heating copper ore very strongly in a furnace with air to produce copper crude metal
- Then what happens when the metal is obtained…? We use the impure copper as the positive electrode in electrolysis cells to make pure copper
- Negatives to smelting and electrolysis?
    - Costs are high as huge amounts of heat and electricity are needed
    - It creates pollution which in turn damages the environment
- Explain the point of using electrolysis with impure copper?
    - Electrolysis is used to purify the impure copper extracted by smelting, or to extract copper from copper solutions
    - Metals are always positively charged, therefore in electrolysis they are attracted to the negative electrode…
    - So where is pure metal deposited? At the negative electrode (cathode)
- Reduction (gaining electrons) equation at cathode?
    - Cu^{2+} (aq) + $2e^-$ -> Cu (s)
- Oxidation (loosing electrons) equation at anode?
    - Cu (s) -> Cu^{2+} (aq) + $2e^-$
- Another way we can extract copper?
    - Scrap iron is added, and as iron is more reactive than copper, it can displace it from its solution…
    - Equation? Iron + copper(II) sulfate -> Iron(II) sulfate + copper

Extracting copper from low-grade copper ores

- Two ways of extracting copper from low-grade ores? ***Bioleaching*** and ***Phytomining***
- Explain bioleaching…?
    - In bioleaching, bacteria feed on low-grade metal ores…
    - We can obtain a solution of copper ions (leachate) from the waste copper ore
    - To extract copper from the leachate we use scrap iron to displace it
- Disadvantages of bioleaching?
    - It is a slow process so scientists are researching ways to speed it up

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8.5 The effect of catalysts

- What is a catalysts? A catalyst speeds up the rate of a chemical reaction but is not used up in the reaction itself…
- Examples of catalysts? Many are transition metals, examples include iron, used to make ammonia, and platinum, used to make nitric acid
- What form is the catalyst normally used in?
    - Powders, pellets, or fine gauzes
- Why? Because this gives them the biggest possible surface area and makes them as effective as possible

Advantages of catalysts in industry

- Although catalysts are expensive, it is often cheaper to use one than to pay for the extra energy needed without one… so catalysts save money and energy
- How do they save the environment? Using high temperatures and pressures often involves burning fossil fuels, so operating at lower temperatures and pressures conserves these non-renewable resources
- They are cost effective as they don't get used up in the reaction, so a tiny amount of catalyst can be used to speed up a reaction over and over again
- Examples of catalysts used in industry?
    - Manufacture of ammonia/Haber process
    - Nitrogen + hydrogen ⇋ ammonia…. This uses an iron catalyst
- Catalysts are very specific however. For example catalytic converters in cars only work with platinum metal which is very expensive, but it is the only metal that will work. Catalytic converters convert carbon monoxide (which is toxic) into carbon dioxide, and nitrogen oxides (which causes acid rain) into nitrogen and oxygen

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9.2 Fractional distillation

Properties of hydrocarbons

- The shorter the molecules……..
    - The lower the boiling point… therefore the quicker the fraction vaporises/condenses in the fractionating column
    - The more volatile they are (higher tendency to turn into a gas)
    - The less viscos (more runny) they are
    - The more flammable (easier to ignite) they are

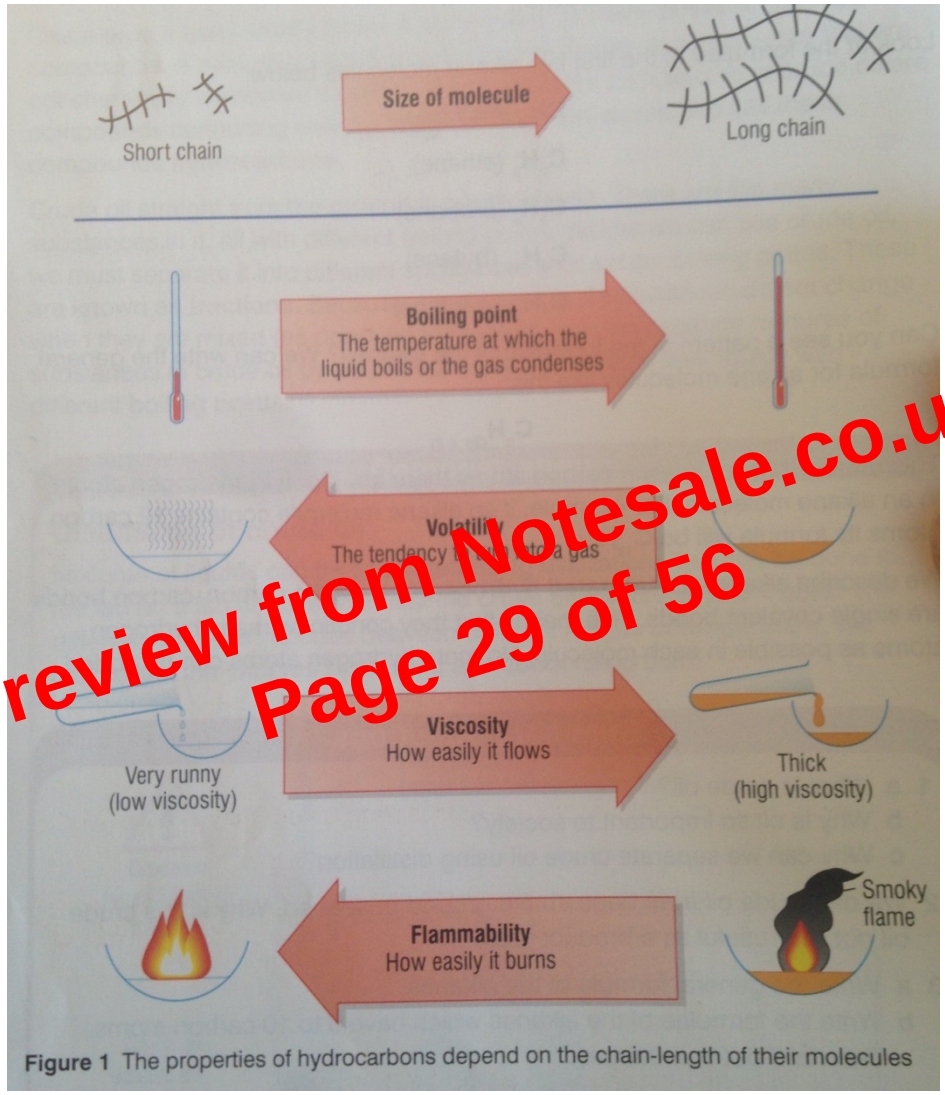

Figure 1 The properties of hydrocarbons depend on the chain-length of their molecules

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Hydrogen – a fuel for the future

- Why is hydrogen seen as the 'fuel of the future'?
    - It burns well with a clean flame
    - Because there is no carbon in the fuel, there are no pollutants made when hydrogen burns and no extra carbon dioxide is added to the air
- There are problems to overcome however…?
    - When mixed with air and ignited, it is explosive, and this presents safety concerns in case of leaks, or accidents…
    - Also vehicles normally run on liquid fuels but hydrogen is a gas, therefore it takes up a much larger volume than liquid fuels, so storage becomes an issue

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12.1 Exothermic and endothermic reactions

- What are exothermic reactions?
    - Exothermic reactions transfer energy from the reacting chemicals to their surroundings. This energy often heats up its surroundings…
- What are endothermic reactions?
    - Endothermic reactions take in energy from their surroundings, and cause a 'drop' in temperature as they happen…

Exothermic reactions

- Example of exothermic reaction?
    - Burning fuels like methane (natural gas)
    - Neutralisation reactions
- What is enthalpy change?
    - Enthalpy change is any temperature change between the reactants and the products of the reaction
- In exothermic reactions, what is the value of enthalpy?
    - Always NEGATIVE

Endothermic reactions

- Examples of endothermic reactions?
    - Thermal decomposition reactions… eg decomposition of calcium carbonate
- Decomposition of calcium carbonate?
    - Calcium carbonate strongly heated…
    - It forms calcium oxide and carbon dioxide
- In endothermic reactions, what is the value of enthalpy?
    - Always POSITIVE

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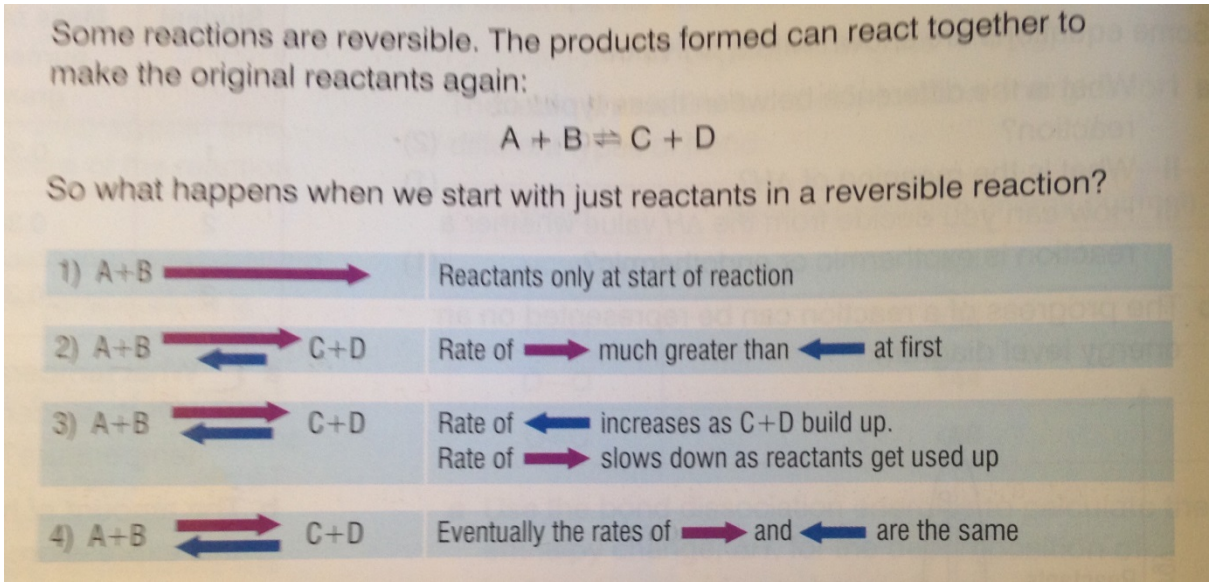
12.2 Using energy transfers from reactions

Warming up

- One time use hand warmers?
    - Oxidation of iron…
    - Iron turns into hydrated iron (III) oxide in an exothermic reaction
    - Sodium chloride is used as a catalyst
    - Lasts for hours
- Many time use hand warmers?
    - Based on the formation of crystals from solutions of a salt
    - Sodium ethanoate is a commonly used salt
    - A supersaturated solution is prepared
    - Small metal disc in the pack starts the exothermic change. When pressed, small particles of metal are scraped off which start off the crystallisation
    - To reuse you boil the pack so the crystals re-dissolve

13.1 Chemical equilibrium



- What happens in a reversible reaction?
  - In a reversible reaction, the products can react to re-form the original reactants
- As the concentration of products builds up…
  - The rate at which they re-form reactants increases…
- What eventually happens?
  - Eventually, both forward and reverse reactions are occurring at the same rate, but in opposite directions. Overall there is no change in the amount of products and reactants. We call this ***equilibrium.***
- **At equilibrium, the rate of the forward reaction equals the rate of the reverse reaction.**

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13.2 Altering condition

The position of equilibrium shifts as if trying to cancel out any change in conditions.

PRESSURE

If the forward reaction produces *more* molecules of gas…	**If the forward reaction produces *fewer* molecules of gas…**
… an increase in pressure decreases the amount of products formed.	… an increase in pressure increases the amount of products formed.
… a decrease in pressure increases the amount of products formed.	… a decrease in pressure decreases the amount of products formed.

- What happens if you *increase pressure* in reversible reactions with gases?
  - Increasing the pressure favours the reaction that forms fewer molecules of gas
- **Changing the pressure affects the equilibrium only if there are different numbers of molecules of gases on each side of the balanced equation**

Energy and equilibrium

TEMPERATURE

If the forward reaction is exothermic…	If the forward reaction is endothermic
…an increase in temperature decreases the amount of products formed.	… an increase in temperature increases the amount of products formed.
… a decrease in temperature increases the amount of products formed.	… a decrease in temperature decreases the amount of products formed.

- What happens if you *increase the temperature* in reversible reactions with gases?
    - The reaction that is endothermic (taking in energy) will be favoured

13.3 Making ammonia – the Haber process

- What does the Haber process allow us to do?
    - It allows us to turn nitrogen in the air into ammonia
- Why is ammonia important?
    - Ammonia is an important chemical for making other products, including fertilisers
- Raw materials of the Haber process?
    - Nitrogen (from the air)
    - Hydrogen (mainly from natural gas)

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What happens in the Haber process?

- Nitrogen and hydrogen are purified, then passed over an iron catalyst at a high temperature (about **450°C**) and a high pressure (about **200 atmospheres**). The product is ammonia.
- This reaction is reversible which means that the ammonia can break down again into nitrogen and hydrogen
- We remove the ammonia by cooling the gases so that the ammonia liquefies, and it can then be separated from the unreacted nitrogen gas and hydrogen gas

What happens to the unreacted nitrogen and hydrogen gases?

- The unreacted nitrogen and hydrogen gases are recycled back into the reaction mixture.

EQUATION FOR HABER PROCESS?

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

14.1 Electrolysis

- What does electrolysis do?
    - Electrolysis breaks down substances using electricity
- What is the electrolyte?
    - The electrolyte is the substance that is broken down by electrolysis
- What is the setup of electrolysis?
    - Two electrodes dip into the electrolyte
    - One is connected to the positive terminal of a power supply (**anode**)
    - The other is connected to the negative terminal of a power supply (**cathode**)
- Why are the electrodes often made of an unreactive substance?
    - So the electrodes do not react with the electrolyte or the products of electrolysis
- So what happens during electrolysis?
    - **During electrolysis, positively charged ions move to the cathode (negative electrode). At the same time, the negative ions move to the anode (positive electrode)**
- Why do ionic substances need to be liquefied before they are electrolyzed?
    - Ionic substances do not conduct electricity when they are solid as their ions are in fixed positions in their giant lattice. When melted however, the ions are free to move around within the liquid and carry their charge towards the electrodes

Electrolysis of solutions

- It is more difficult to predict what will be formed when electrolysing ionic compounds in solution and not as molten compounds
- Can covalent compounds be electrolysed?
    - Normally no. Unless they react in water to form ions

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14.2 Changes at the electrodes

- What is gaining electrons called? **Reduction**
- What is losing electrons called? **Oxidation**
- Half equation for cathode (negative electrode)
    - $Pb^{2+} + 2e^- \rightarrow Pb$
- Half equation for anode (positive electrode)
    - $2Br^- \rightarrow Br_2 + 2e^-$

The effect of water

- What happens when electrolysis happens in aqueous solutions?
    - The less reactive element (hydrogen or metal) forms at the cathode
    - At the anode, usually there is oxygen from the discharged hydroxide ions… but this oxygen normally combines with carbon to form **CARBON DIOXIDE**
- So why do the carbon anodes need to be replaced regularly
    - Their slow reaction with oxygen mean they gradually burn away