# Topic: Rates of Reaction

**Duration: 8 lessons**

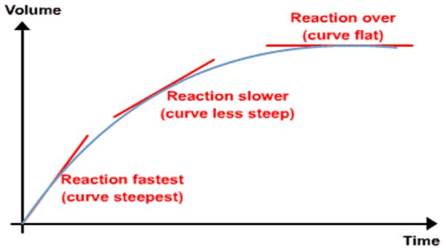
**Composite Test**

## Key vocabulary:

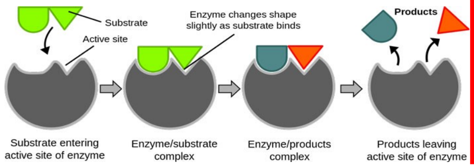
Rate
Reaction
Exothermic
Endothermic
Concentration
Catalyst
Enzyme
Reaction
Profile
Collision
Frequency
Effervescence
Enzyme
Substrate
Complex
Activation energy
Precipitate
Particles
Pressure
Compressed
Surface area
Proportion
Volume
Ratio

## Core Knowledge

**Rate of reaction** – the speed of a reaction.
**Activation energy** – the minimum energy needed for a reaction to occur.
**Exothermic change** – a reaction that gives out heat energy overall resulting in a rise in temperature.
**Endothermic change** – a reaction that takes in. energy overall resulting in a temperature decrease.
**Concentration** – a measure of how many particles are in a given volume (not area).
**Catalyst** – a substance that speeds up a chemical reaction but without being chemically changed
**Enzyme** – a biological catalyst made from protein molecules.
**Reaction profile diagram** – shows the energy changes that take place during a reaction.
**Collision Frequency** – number of collisions per unit time e.g. number of collisions per second.

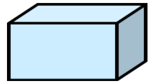
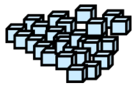
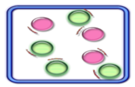
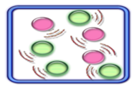
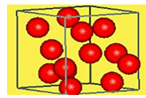
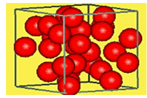
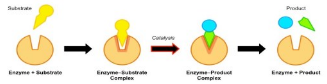



$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

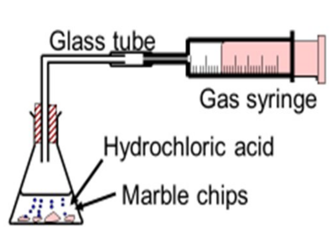



## Powerful Knowledge

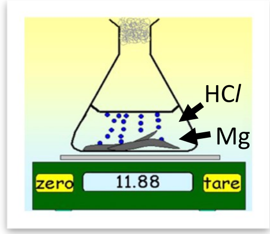
Rates of Reaction—Collision Theory

| Factor affecting rate | Slower reaction | Faster reaction | Explanation |
|---|---|---|---|
| Surface area |  |  | The bigger the surface area to volume ratio the higher the collision frequency |
| Temperature |  |  | The higher the temperature the faster the particles move so the higher the collision frequency **AND** the greater the proportion of collisions equal to or |
| Concentration/ pressure |  |  | The higher the concentration/pressure the more particles there are in a given volume so the higher the collision frequency |
| Catalyst |  | | A catalyst lowers the activation energy by providing an alternative reaction pathway which means there is a greater proportion of successful collisions |

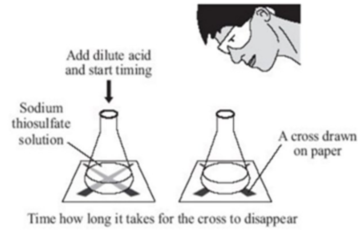
Practical methods for following rate of reaction:




If a gas is made you can collect it in a gas syringe and read off the volume every 30-seconds.




Alternatively, if a gas is made you can allow it to escape and measure the decrease in mass every 30-seconds. Note that the cotton wool is to stop the solution spattering and




If a precipitate (solid) is made use the 'disappearing cross' method to follow the rate.

## Links to previous and future topics

**Links to KS2:**

There are no previous links to this content.

**Links to KS3:**

Some of the ideas from this unit link to the following topics

Particles
Diffusion
States of matter
Food and Digestion
Pressure

**Links to KS4:**

There are a number of links to content within this key stage

**Biology:**
Key Concepts in Biology
Enzymes

**Chemistry:**
Diffusion
Haber process
Particles
Equilibria

## Impressive reading

To complete the variety of experiments offered in this unit you will need to read and comprehend instructions from a number of method sheets and follow to accurately perform practical work and comply with lab rules and safety.

## Impressive speaking

During class discussions you will present your findings from practical work by analysing your data and drawing conclusions using key terminology to present and share ideas to your peers.

## Impressive writing

Here you will write conclusions which link results and theory using keywords and terminologies. In preparation for extended written responses to exam questions you will also practice engaging with a selection of past paper questions.

## Resilience

Remembering the three methods to measure and the four factors effecting rate of reaction can be tricky! It is all about revisiting these new ideas. Spend 10-15 minutes after each lesson recapping what you have learnt to help build your core and powerful knowledge in these areas. Remember, never give up!

## Employability

There are an extensive selection of careers that are linked to this topic:

Analytical Chemist, Chemical Engineer, Chemistry Teacher, Forensic Scientist, Geochemist, Hazardous Waste Chemist, Materials Scientist., Pharmacologist and many, many more!

# Topic 6: Groups

# Duration: 6 lessons

# Composite:

**Key Vocabulary:**

Effervescence

Displacement

Oxidation

Reduction

Inertness

Flammability

Physical property

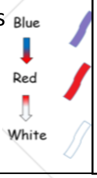
Electronic configuration

Relative

Predict

**Test for $Cl_2$**

Damp blue litmus paper turns red then bleaches white.




## Group 1 The Alkali Metals and Water

**Example:** lithium + water → lithium hydroxide + hydrogen

$2Li + 2H_2O \rightarrow 2LiOH + H_2$

**Observations:** Effervescence (fizzing) due to hydrogen being produced; moves around on surface; melts and gets smaller; alkaline solution produced; crimson red flame when hydrogen is lit.

**Reactivity** increases down the group. The outer electron is lost more easily as it is further from the attraction of the nucleus and there is more electron shielding.

## Group 7 Reactions of the Halogens

**Reactivity** decreases down the group. It is more difficult to gain an electron as the outer shell is further from the attraction of the nucleus and there is more electron shielding.

metal + halogen → metal halide

**Example**: sodium + chlorine → sodium chloride

$2Na + Cl_2 \rightarrow 2NaCl$

hydrogen + halogen → hydrogen halide

**Example:** hydrogen + bromine → hydrogen bromide

$H_2 + Br_2 \rightarrow 2HBr$

*The hydrogen halides formed readily dissolve in water to form acidic solutions.*

**Displacement Reactions**

A more reactive halogen can displace (push out) a lesser reactive halogen from its compound in aqueous solution and can be used to compare reactivity.

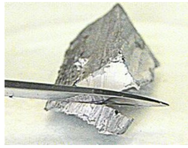
**Example:** chlorine + sodium bromide → sodium chloride + bromine (orange/brown)

**HIGHER LEVEL ONLY –** explain why displacement reactions are REDOX reactions.

**Powerful Knowledge components critical to commit to long term memory:**

Groups in the Periodic Table:

***Group 1*** The Alkali Metals – Li, Na and K



Soft metals that can be easily cut with a knife and have relatively low melting points

***Group 7*** The Halogens – $Cl_2$ $Br_2$ and $I_2$

Yellow/green gas

red/brown liquid

Grey solid

***Group 0*** The Noble Gases – He, Ne and Ar are unreactive gases as they already have a full outer shell of electrons.

| Name | Use | Why |
|---|---|---|
| Helium | Balloons/ Airships | Less dense than air so rises |
| Neon | Fluorescent lights | Glows when electric current passed through |
| Argon | Light bulbs | Unreactive with metal filament |

**Links to previous and future topics**

KS3 Elements, compounds and reactions

KS3 Acids and Alkalis

KS3 Metals and Reactivity

KS3 Microorganisms

KS3 The Periodic Table

KS3 Chemical Reactions

KS5 Periodic Table

KS5 Halogens

KS5 Redox

| Impressive reading | Impressive speaking | Impressive writing | Resilience | Employability via: |
|---|---|---|---|---|
| Following written instructions in experiments and CC pdf | Should chlorine be added to drinking water? | Write up of practicals | Explaining concept of reactivity | Job opportunities water treatment, public health, chemical industry etc. |

**CULTURAL CAPITAL:** Benefits and risks of adding chlorine to drinking water. http://www.bioray.com/content/Chlorine.pdf and John Snow articles. Also, http://www.bbc.co.uk/history/historic_figures/snow_john.shtml for shorter read.

**SEND**

- Opening activity/theme is Knowledge Recall to ensure learner buy in
- Opportunities for retrieval practice and building on prior knowledge using Knowledge Recall.
- Multi-sensory approach using reading, listening, watching, doing practicals, talking, observing demonstrations…
- Repetition of key vocabulary in every lesson
- Curriculum time allocated for the explicit teaching of key vocabulary
- Skills ordered logically and sequenced with an increase in complexity
- Links to prior learning explicitly highlighted to support non-verbal reasoning – then, now, next
- Activities are scaffolded with over-learning of previous content to encourage independence

| Topic: KS4: Topic 4 Extracting metals and Equilibria – Obtaining and using metals (C) | Duration: 4 lessons | Composite: Unit test |
|---|---|---|

**Key vocabulary:**

Reactivity, Displacement, Tendency, Salt, Electrons, Ions, Cations, Oxidised, Reduction, Ore, Extraction, Electrolysis, Recycling, Lifetime assessment (LTA) Reversible, Reactants, Products, Dynamic equilibrium, Rate, Haber Process, Catalyst, Temperature, Pressure

**Core knowledge Components**

**Powerful knowledge components crucial to commit to long term memory (in red box)**

1. Know the products of a reaction between metal and water. Products are a metal hydroxide (forming an alkaline solution) and hydrogen gas.

   Metal + water -> metal hydroxide + water

2. Recall that fairly reactive metals react with acids to produce a salt and hydrogen gas.

   Acid + metal → salt + hydrogen

3. Know that the more reactive metals will react with oxygen more quickly and recall the word equation for metals reacting with oxygen:

   Metal + oxygen -> metal oxide

4. Explain how displacement reactions can show which metal is the most reactive.

   **Applying the Reactivity Series of Metals**

   *Let's assume Metal X is higher in the reactivity series (so more reactive) than Metal Y.*

   *This means that Metal X can react with Metal Y and reduce the Salt (or Oxide) of Metal Y.*
   *In other words, Metal X will* ***displace*** *Metal Y from its compound because Metal X is more reactive than Metal Y.*

   For example,

   Fe, Zn and Mg are more reactive than Cu, so,

   $Fe_{(s)} + CuCl_{2(aq)} \rightarrow FeCl_{2(aq)} + Cu_{(s)}$
   $Zn_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow Zn(NO_3)_{2(aq)} + Cu_{(s)}$
   $Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$

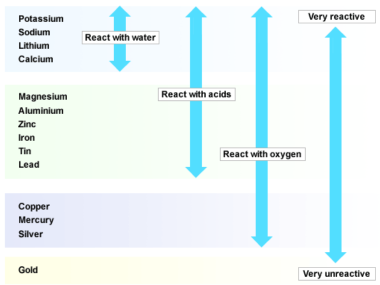
5. Recall that: most metals are extracted from ores found in the Earth's crust, and unreactive metals are found in the Earth's crust as the uncombined elements.

- Most metals are found as compounds that require chemical reactions to extract the metal but gold is very unreactive and can be found in the Earth as itself.

6. Recall that the extraction of metals involves reduction of ores

- Metals less reactive than carbon.
- Can be extracted from their oxides by reduction with carbon

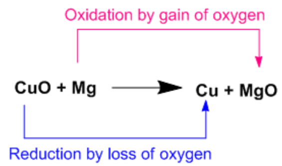
**1. Deduce the relative reactivity of some metals, by their reactions with water, acids and salt solutions.**

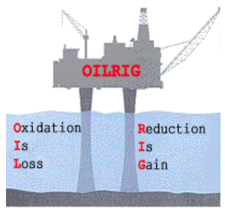



**2. Explain the reactivity series of metals (potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen), copper, silver, gold) in terms of the reactivity of the metals with water and dilute acids and that these reactions show the relative tendency of metal atoms to form cations.**

- **When metals react with other substances, metal atoms form positive ions (they lose electrons to become cations)**
- **Reactivity of a metal is related to its tendency to form positive ions (cations) more reactive metals can form cations more easily**

**3. Explain oxidation as the gain of oxygen and reduction as the loss of oxygen.**




**4. Explain why the method used to extract a metal from its ore is related to its position in the reactivity series and the cost of the extraction process, illustrated by heating with carbon (including iron) and electrolysis.**

**Links to previous and future topics**

KS3: Elements and compounds, The Periodic Table, Separation Techniques, Metals and Reactivity

KS4: Obtaining & Using Metals, The Periodic Table

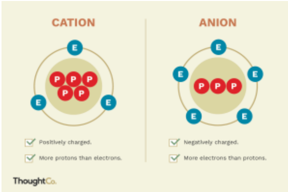
KS3: Elements and compounds, The Periodic Table, Separation Techniques, Metals and Reactivity

KS4: Obtaining & Using Metals, The Periodic Table, Dynamic Equilibria

7. Recall the general word equation for extracting a metal compound from its ore and give an example of a symbol equation.

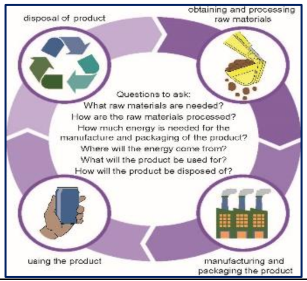
- Metal compound + carbon → metal + carbon dioxide
- $2Fe_2O_3$ (s) + 3C(s) -> 4Fe(l) + $3CO_2$ (g)

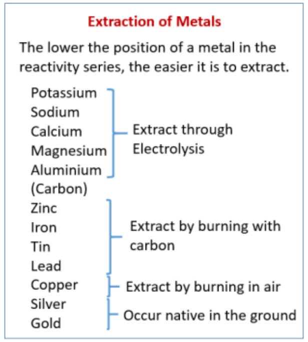
8. Explain how cations and anions are formed.




9. Describe that a life time assessment for a product involves the consideration of the effect on the environment of obtaining the raw materials, manufacturing the product, using the product and disposing of the product when it is no longer useful.

● These are carried out to assess the environmental impact of products in each of these stages:
o Extracting and processing raw materials
o Manufacturing and packaging
o Use and operation during its lifetime
o Disposal at the end of its useful life, including transport and distribution at each stage
● Use of water, resources, energy sources and production of some wastes can be fairly easily quantified
● Allocating numerical values to pollutant effects is less straightforward and requires value judgements, so LTA (life time assessment) is not a purely objective process
● Selective or abbreviated LTAs can be devised to evaluate a product but these can be misused e.g. in support of claims for advertising purposes




**● Can only be extracted by reduction of carbon if metal is less reactive - carbon displaces the metal from the ore**
**● If more reactive than carbon, electrolysis can be used (metals less reactive than carbon can also be extracted this way)**
**● Electrolysis is expensive due to large amounts of energy needed to melt the compounds and to produce the electrical current (so you wouldn't extract a metal using electrolysis if it could be done more cheaply using carbon)**

**5. Explain how a metals' relative resistance to oxidation is related to its position in the reactivity series.**
**● Relative resistance to oxidation is the same as relative resistance to losing electrons / forming positive metal ions**
**● Less reactive a metal is, the more resistant it is to oxidation, because for a metal to react, it forms a positive metal ion by losing electrons (loss of electrons=oxidation)**

**6. Evaluate the advantages of recycling metals, including economic implications and how recycling can preserve both the environment and the supply of valuable raw materials.**
**● Recycling is important to achieve sustainable development**
**o Requires less energy to melt and remould metals than it does to extract new metals from their ores**
**o Mining ores is bad for the environment as large quarries are created, which produce noise pollution and dust**
**o Also, recycling allows for waste metals to be reused, saving money, helping the environment and the supply of valuable raw materials (meaning metal ores will last longer).**

**7. Evaluate data from a life cycle assessment of a product.**

**1. Recall that chemical reactions are reversible, the use of the symbol ⇌ in equations and that the direction of some reversible reactions can be altered by changing the reaction conditions.**

- **The direction of the reaction can be changed by changing the conditions E.g. if the forwards reaction takes place in hot conditions, lowering the temperature can allow the reverse reaction to take place**

**2. Explain what is meant by dynamic equilibrium.**

| | | | | |
|---|---|---|---|---|
| | 1. Recall that the ⇌ symbol is used to show that a reaction is reversible.<br>• E.g. The Haber Process: nitrogen + hydrogen ⇌ ammonia<br>2. Describe the connection between reactants and products during dynamic equilibrium.<br>• During the reaction, the same percentage of reactants and products are formed at the same rate.<br>3. Identify where the products of the Haber process come from.<br>• nitrogen - extracted from the air<br>• hydrogen - obtained from natural gas<br>4. Recall the conditions for the Haber process.<br>• **The purified gases (nitrogen and hydrogen) are passed over a catalyst of iron at:**<br>• **a high temperature (about 450 °C) and**<br>• **a high pressure (about 200 atmospheres).** | **3. Describe the formation of ammonia as a reversible reaction between nitrogen and hydrogen and that it can reach a dynamic equilibrium.**<br>• **Ammonia is manufactured using the Haber process. It is used to make nitrogen-based fertilisers. This is a reversible reaction between nitrogen (from the air) and hydrogen (from natural gas) that can reach dynamic equilibrium. The reaction is illustrated below:**<br>**Word equation:** **Nitrogen + hydrogen ⇌ ammonia**<br>**Formula equation:** $N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$ | | |
| **Impressive reading** | **Impressive speaking** | **Impressive writing** | **Resilience** | **Employability via:** |
| **1 lesson. Reading for information** | **Able to explain models of dynamic equilibrium.**<br>**Explain the need for fertilisers and impact on food availability (culture capital)** | **Structured answers. Plastic bags vs Paper bags** | **Explaining how conditions push reverse changes in line with Chataliers principle ( simple terms)** | Product Design involving plastics, ceramics, polymers and composites; material scientist, engineering: composite, chemical, polymer; mining, artist, architect |

**SEND**

- Opening activity/theme is opening slide to ensure learner buy in
- Opportunities for retrieval practice and building on prior knowledge: knowledge recall slide
- Multi-sensory approach using reading, listening, practical work, watching videos, dual-coding, practical work, paired working, observing teacher demonstrations
- Repetition of key vocabulary in every lesson
- Curriculum time allocated for the explicit teaching of key vocabulary
- Skills ordered logically and sequenced with an increase in complexity
- Links to prior learning explicitly highlighted to support non-verbal reasoning
- Texts used/alternative texts available with a consideration to reading age

# KS4: Topic 5 Separate chemistry 1 – Chemical Cells & Fuel Cells

Keywords:

Cells, Electricity, Voltage, Reactants, Electrolyte, Electrode, Anode, Cathode, Oxidised, Potential difference, Rechargeable

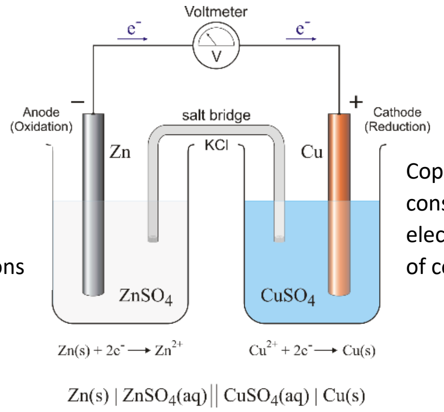
The voltage produced by a cell is dependent upon a number of factors including the type of electrode and electrolyte used.

Chemical Cells:

A chemical cell converts chemical energy into electrical energy. Most batteries are chemical cells. A chemical reaction takes place inside the battery and causes electric current to flow. There are two main types of batteries - those that are rechargeable and those that are not.

A chemical cell consists of 2 metals in solution of their metal ions and a salt bridge to allow ions to flow from one solution to another.

Zinc half of cell consists of a zinc electrode in a solution of zinc ions




Copper half of cell consists of a copper electrode in a solution of copper ions

Batteries go flat because one of the reactants is used up and a voltage is no longer produced.

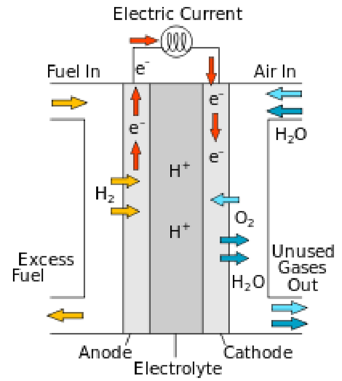
Fuel Cells:

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A Fuel cell uses hydrogen gas ($H_2$) and oxygen gas ($O_2$) as fuel at each of the electrodes. The products of the reaction in the cell are water, electricity, and heat.

The overall reaction in a hydrogen fuel cell involves the oxidation of hydrogen to produce water. The fuel is oxidised electrochemically within the fuel cell to produce a potential difference (a voltage).

hydrogen + oxygen → water

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$




| Strengths | Weaknesses |
|---|---|
| **Produce only water as waste** | **Difficult to transport/store hydrogen so are not suitable for portable devices** |
| **Keep producing fuel if fuel keeps being supplied** | **Expensive to make** |

Hydrogen fuel cells offer a potential alternative to rechargeable cells and batteries.

# KS4: Topic 5 Separate chemistry 1 – Dynamic Equilibria (C)

Balanced symbol equation for the reaction between nitrogen and hydrogen to produce ammonia.

$$2H_2 + N_2 \rightarrow 2NH_3$$

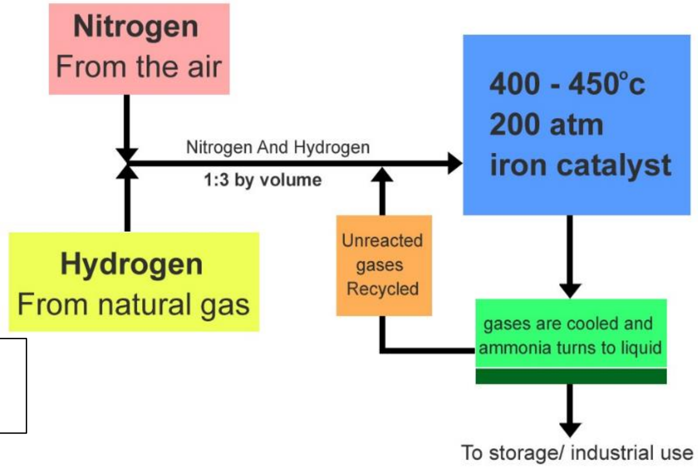
Keywords:

Reversible, Reaction, Haber process, Equilibrium, Kinetic, Optimum, Pressure, Concentration, Volume, Catalyst, Yield, Fertilisers, NKP.

A **reversible reaction** is a **reaction** where the reactants and products **react** together to give the reactants back. A and B can **react** to form C and D or, in the reverse **reaction**, C and D can **react** to form A and B.

The Haber Process

This process uses nitrogen from the air and hydrogen from natural gas to form ammonia. The reaction is reversible and uses **optimum conditions** and a catalyst in order to reach dynamic equilibrium.




NPK Fertilisers – contain nitrogen, phosphorous and potassium used to promote plant growth

**Many fertilisers contain nitrogen, phosphorus and potassium to promote plant growth.** They are therefore known as NPK fertilisers. **Ammonium nitrate** is a salt used as a fertiliser, produced from the reaction between **ammonia** and **nitric acid**.

ammonia + nitric acid → ammonium nitrate

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$


Preparation of ammonium sulfate from ammonia solution and dilute sulfuric acid.

- Add known volume of dilute sulfuric acid to an evaporating basin.
- Add known volume and concentration of ammonia to the sulfuric acid.
- Test with universal indicator paper to ensure neutral.
- Evaporate the solution slowly using Bunsen burner to concentrate the solution.
- Cool until crystals form; dry the sample.

In the lab:

Reactants: ammonia solution and dilute sulfuric acid (bought from chemical manufacturers)

SMALL scale (very little is produced)

Only involves a few stages (titration then crystallisation)

VS

Industry:

Reactants: natural gas, air, water (to make ammonia) and sulfur, air, water (to make sulfuric acid)

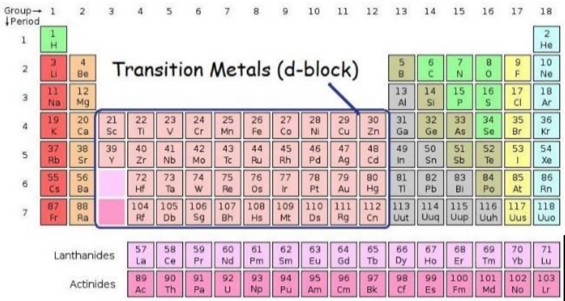
LARGE scale (produces a lot)

Many stages required (need to make ammonia and sulfuric acid, react accurate volumes then evaporate)

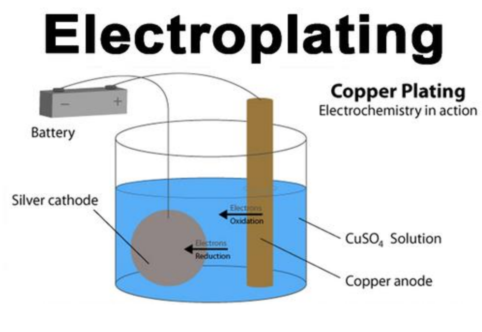
# KS4: Topic 5 Separate chemistry 1 - Transition metals, alloys and corrosion

**Keywords:**

Properties, Density, Compound, Catalysts, Corrosion, Rusting, Barrier, Galvanising, Electrolysis, Electroplating, Anode, Cathode, Alloy, Malleable



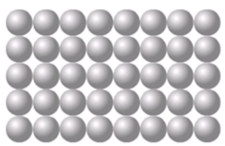

| Transition metals and their properties | |
|---|---|
| Most metals are transition metals | 1. High melting points<br>2. High density<br>3. Form coloured compounds<br>4. Used as catalysts (without being used up themselves) |

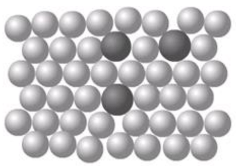



**Electroplating** - A process that uses an electric current to reduce dissolved metal cations so that they form a thin coherent metal coating on an electrode

| | | |
|---|---|---|
| Corrosion | *The destruction of materials by chemical reactions with substances in the environment* | An example of this is iron rusting; iron reacts with oxygen from the air to form iron oxide (rust) water needs to be present for iron to rust. |
| Preventing corrosion | *Coatings can be added to metals to act as a barrier to stop water and air reacting with the metal* | Examples of this are greasing, painting and electroplating. Aluminum has an oxide coating that protects the metal from further corrosion - exclusion of oxygen and water |
| Sacrificial corrosion | *When a more reactive metal is used to coat a less reactive metal* | The coating will react with the air and not the underlying metal. An example of this is zinc used to galvanise iron |
| Electroplating | *Used to improve the appearance and/or resistance to corrosion. Acts as a barrier from air and water. Gold is used as it is more attractive.* | The metal to be plated as the cathode and the metal you're plating it with as the anode, then have a solution containing ions of the metal being used to do the plating |

**Alloy - Mixture of two or more elements at least one of which is a metal. Most metals in everyday use are alloys. Pure copper, gold, iron and aluminium are too soft for everyday use.**





In a pure metal, all the + metal ions are the same size and in a regular arrangement, allowing the layers to slide over each other relatively easily, making the metal soft and malleable.

In an alloy, you have + ions of different metals, which have different sized ions. This disrupts the regular structure and prevents the ions being able to slide as easily, leaving a much harder, stronger metal.

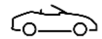
Steel – mixture of Carbon and Iron

Alloys can be designed to specific uses.

o Low-carbon steels are easily shaped - used for sheeting (malleable)

o High carbon steels are hard - used for cutting tools

o Stainless steels (containing chromium and nickel) are resistant to corrosion - used for cutlery

| | |
|---|---|
| Aluminium: low density, used for aircraft |  |
| Copper: good conductor, used in electrical cables |  |
| Gold: good resistance to corrosion, used in jewellery |  |
| Magnalium (aluminum + magnesium): low density, used in cars and planes |  |
| Brass (copper + zinc): hard, resistant to corrosion, used in coins, locks, door knobs |  |