Chemical Changes

Metal	Reaction with cold water	Reaction with dilute acids	Reactivity	Extraction method
Potassium	Violent	Violent	Most reactive	Electrolysis
Sodium				
Lithium				
Calcium	Fast	Rapid		
Magnesium	Very slow			
Aluminium	no reaction	Slow		
(Carbon)				
Zinc	no reaction	Slow		Heating with carbon
Iron	Rusts slowly			
(Hydrogen)				
Copper	No reaction	No reaction		Heating with carbon
Gold			Least reactive	Found pure

The Reactivity Series
- When metals react with other substances the metal atoms form positive ions.
- The reactivity of a metal is related to its tendency to form positive ions.
- Metals can be arranged in order of their reactivity in a reactivity series.
- The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids.
- The non-metals hydrogen and carbon are often included in the reactivity series.
- A more reactive metal can displace a less reactive metal from a compound.

Extracting iron and copper
- **Unreactive metals** such as gold are found in the Earth's **crust** as the uncombined **elements**. However, most metals are found combined with other elements to form **compounds**.
- Most metals are extracted from **ore** found in the Earth's crust. An ore is a rock that contains enough of a metal or a metal compound to make extracting the metal worthwhile.

Extraction methods
- The **extraction** method used depends upon the metal's position in the **reactivity series**. In principle, any metal could be extracted from its compounds using **electrolysis**. However, large amounts of **electrical energy** are needed to do this, so electrolysis is expensive.
- If a metal is less **reactive** than carbon, it can be extracted from its compounds by heating with carbon. Copper is an example of this.

Copper oxide + carbon → copper + carbon dioxide

$$2CuO_{(s)} + C_{(s)} \rightarrow 2Cu_{(l)} + CO_{2(g)}$$

- Copper oxide is **reduced** as carbon is **oxidised**, so this is an example of a **redox** reaction.

A **base** is any substance that reacts with an **acid** to form a **salt** and water only. This means that metal oxides and metal hydroxides are bases.
Bases that are **soluble** in water are called **alkalis** and they **dissolve** in water to form **alkaline solutions**. For example:
- copper oxide is a base, but it is not an alkali because it is **insoluble** in water
- sodium hydroxide is a base, and it dissolves in water so it is also an alkali

The pH Scale and Neutralisation
Acids produce hydrogen ions (H^+) in aqueous solutions. Aqueous solutions of alkalis contain hydroxide ions (OH^-). The pH scale, from 0 to 14, is a measure of the acidity or alkalinity of a solution, and can be measured using universal indicator or a pH probe. A solution with pH 7 is neutral. Aqueous solutions of acids have pH values of less than 7 and aqueous solutions of alkalis have pH values greater than 7. In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation:

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

Strong & Weak Acids – *[Higher tier]*
A strong acid is completely ionised in aqueous solution. Examples of strong acids are hydrochloric, nitric and sulfuric acids. A weak acid is only partially ionised in aqueous solution. Examples of weak acids are ethanoic, citric and carbonic acids. For a given concentration of aqueous solutions, the stronger an acid, the lower the pH. As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.

Chemical Changes

Reactions with Acid

The general formula for the reaction of an acid and metal is:

acid + metal → salt + hydrogen

For example:

hydrochloric acid + magnesium → magnesium chloride + hydrogen

$2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

acid + metal oxide → salt + water

For example:

sulfuric acid + copper oxide → copper sulphate + water

$H_2SO_{4(aq)} + CuO_{(s)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$

Alkalis are soluble bases. A salt and water are produced when acids react with alkalis. In general:

acid + alkali → salt + water

For example:

nitric acid + sodium hydroxide → sodium nitrate + water

$HNO_{3(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3(aq)} + H_2O_{(l)}$

The general formula for an acid reacting with a metal carbonate is:

acid + metal carbonate → salt + carbon dioxide + water

For example:

hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water

Redox Reactions – *[Higher tier]*

Oxidation is the loss of electrons and reduction is the gain of electrons.

Reduction and **oxidation** happen at the same time, so the reactions are called redox reactions.

The reactions of acids with metals are **redox reactions**. For example, the **ionic equation** for the reaction of magnesium with hydrochloric acid is:

$2H^+_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

This ionic equation can be split into two **half equations**:

- $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2e^-$ **(oxidation)**
- $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$ **(reduction)**

Notice that:

- magnesium atoms lose **electrons** - they are **oxidised**
- hydrogen ions gain electrons - they are **reduced.**

Using Electrolysis to Extract Metals

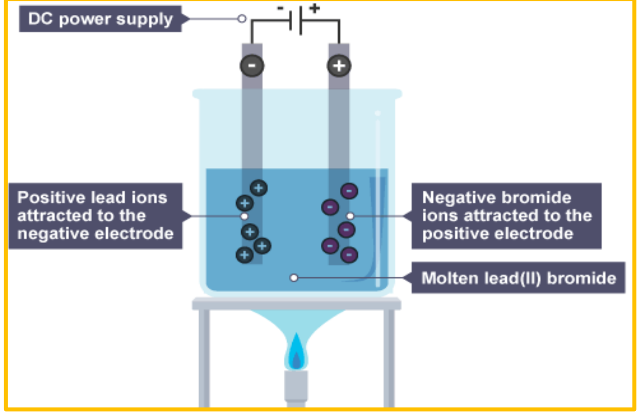
Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current. Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode (anode).

Naming Salts

Hydrochloric acid makes chloride salts; sulphuric acid makes sulphate salts; nitric acid makes nitrate salts

Required practical: making soluble salts

1. Make a saturated solution by stirring copper oxide into sulphuric acid until no more will dissolve.
2. Filter the solution to remove excess solid copper oxide.
3. Half fill a beaker with water and heat it over a Bunsen burner. Place an evaporating dish on top of the beaker.
4. Add some of the solution to the evaporating basin and heat until crystals begin to form.
5. Pour the remaining liquid into a crystallising dish and leave to cool for 24 hours.
6. Remove crystals with a spatula and pat dry between paper towels.



Electrolysis

When an ionic compound is melted or dissolved in water, the ions are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes. Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode). Ions are discharged at the electrodes producing elements. This process is called electrolysis.

Metal Oxides

- Metals can react with oxygen to make compounds called **oxides**.
- The reactions are **oxidation** reactions because the metal gains oxygen.
- Metal oxides are **bases**. This means they can neutralise an acid.
- Non-metal oxides dissolve in water to make acidic solutions.
- If oxygen is lost from a compound, this is called **reduction.**

Electrolysis of Molten Compounds

When a simple ionic compound (e.g. lead bromide) is electrolysed in the molten state using inert electrodes, the metal (lead) is produced at the cathode and the non-metal (bromine) is produced at the anode.

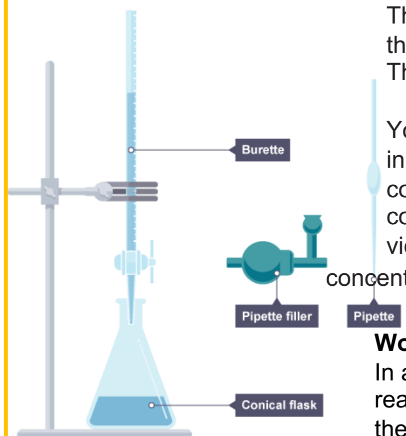
Chemical Changes

Electrolysis of Aqueous Solutions

The ions discharged when an aqueous solution is electrolysed, using inert electrodes, depend on the relative reactivity of the elements involved. At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen. At the positive electrode (anode), oxygen is produced unless the solution contains halide ions in which case the halogen is produced. This happens because in the aqueous solution water molecules break down producing hydrogen ions and hydroxide ions that are discharged.

Required Practical Titration *(Separate Chemistry Only)*

1. Use the pipette and pipette filler to add 25 cm^3 of alkali to a clean conical flask.
2. Add a few drops of **indicator** and put the conical flask on a white tile.
3. Fill the burette with acid and note the starting volume.
4. Slowly add the acid from the burette to the alkali in the conical flask, swirling to mix.
5. Stop adding the acid when the end-point is reached (the appropriate colour change in the indicator happens). Note the final volume reading.



The difference between the reading at the start and the final reading gives the volume of acid added. This volume is called the titre.

You can calculate the amount of a substance in **moles** in a solution if you know the volume and concentration. You can also work out the concentration of an acid reacting with an alkali, or vice versa.

concentration in mol/dm^3 = amount in mol ÷ volume in dm^3

Worked example:

In a titration, 20cm^3 of 1.0mol/dm^3 sulphuric acid reacted with 25cm^3 of sodium hydroxide. What was the concentration of sodium hydroxide?

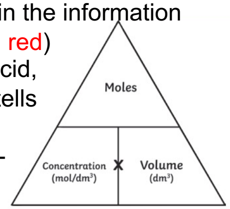
	Acid (H_2SO_4)	Alkali (NaOH)
Moles	0.02	0.04
Concentration mol/dm^3	1.0	1.6
Volume dm^3	0.02	0.025

Write out a balanced symbol equation for the reaction:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Draw a table as shown and fill in the information given in the question (shown in red)

Work out number of moles of acid, (shown in blue). The equation tells us there are twice as many moles of alkali (0.04). Finally we can work out the concentration - **moles/volume = 1.6mol/dm^3**



Required practical: Electrolysis of Aqueous Solutions

This required practical involves developing a **hypothesis**.

An investigation starts with a scientific question, for example:

- What are the products of electrolysis of aqueous solutions?
- Is there a pattern in the products of electrolysis of aqueous solutions?

The first step in answering a scientific question is to develop a hypothesis. A hypothesis is an idea to be tested, which is backed up by scientific knowledge.

Suitable hypotheses are:

- a non-metal will be produced at the positive electrode because non-metal ions are negative.
- solutions that include ions of metals that are low in the reactivity series produce the metal at the negative electrode (not hydrogen) because ions of unreactive metals have a greater tendency to gain electrons.

The hypothesis can then be used to make predictions, such as 'In the electrolysis of copper chloride, the product at the positive electrode will be chlorine.'

The set up below is suitable. The positive electrode is connected to the positive terminal of a dc power pack. The negative electrode is connected to the negative terminal of the power pack.

Test solutions

It is best to test at least five solutions. Suitable solutions include copper sulphate, copper chloride, sodium chloride, sodium nitrate, sodium bromide. There are many more.

Identifying the products

Any gases produced can be collected in the test tubes. They need to be stoppered and tested later. Gas tests include:

1. hydrogen - lighted splint goes out with a squeaky pop
2. oxygen - a glowing splint relights
3. chlorine - damp blue litmus paper turns red and is then bleached white.

The electrodes need to be examined carefully each time, to see if a metal has been deposited on them.

Concentra