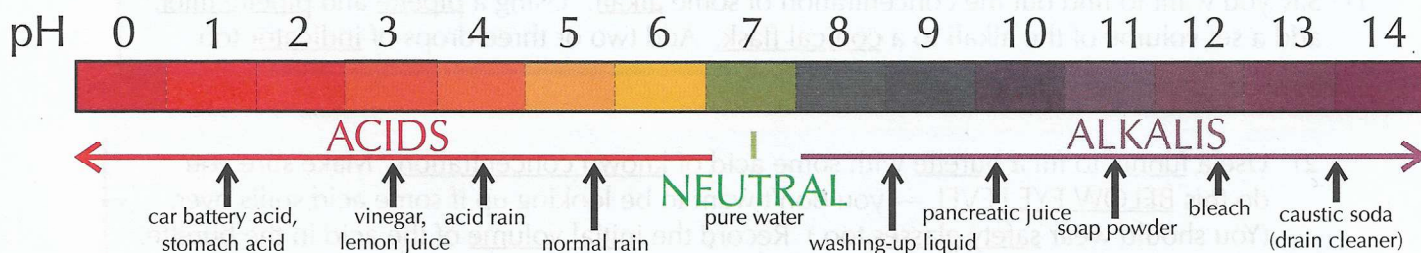


Acids and Bases

Acids and bases crop up everywhere in chemistry — so here's the lowdown on the basics of pH...

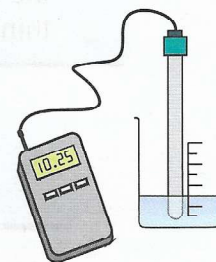
The pH Scale Goes From 0 to 14

- 1) The pH scale is a measure of how acidic or alkaline a solution is.
- 2) The lower the pH of a solution, the more acidic it is.
The higher the pH of a solution, the more alkaline it is.
- 3) A neutral substance (e.g. pure water) has pH 7.



You Can Measure the pH of a Solution

- 1) An indicator is a dye that changes colour depending on whether it's above or below a certain pH. Some indicators contain a mixture of dyes that means they gradually change colour over a broad range of pH. These are called wide range indicators and they're useful for estimating the pH of a solution. For example, universal indicator gives the colours shown above.
- 2) A pH probe attached to a pH meter can also be used to measure pH electronically. The probe is placed in the solution you are measuring and the pH is given on a digital display as a numerical value, meaning it's more accurate than an indicator.



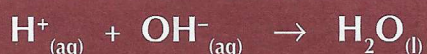
Acids and Bases Neutralise Each Other

- 1) An acid is a substance that forms an aqueous solution with a pH of less than 7. Acids form H⁺ ions in water.
- 2) A base is any substance that will react with an acid to form a salt.
- 3) An alkali is a base that dissolves in water to form a solution with a pH greater than 7. Alkalis form OH⁻ ions in water.

The reaction between acids and bases is called neutralisation:



Neutralisation between acids and alkalis can be seen in terms of H⁺ and OH⁻ ions like this:



Hydrogen (H⁺) ions react with hydroxide (OH⁻) ions to produce water.

When an acid neutralises a base (or vice versa), the products are neutral, i.e. they have a pH of 7. An indicator can be used to show that a neutralisation reaction is over.

Interesting fact — your skin is slightly acidic (pH 5.5)

When you mix an acid with an alkali, hydrogen ions from the acid react with hydroxide ions from the alkali to make water. The leftover bits of the acid and alkali make a salt.

Titration

Titration is a method of analysing the concentrations of solutions. They're pretty important.

Titration is Used to Find Out Concentration

Titration allows you to find out exactly what volume of acid is needed to neutralise a measured volume of alkali — or vice versa. You can then use this data to work out the concentration of the acid or alkali (see page 80). Here's how to do a titration:

- 1) Say you want to find out the concentration of some alkali. Using a pipette and pipette filler, add a set volume of the alkali to a conical flask. Add two or three drops of indicator too.
- 2) Use a funnel to fill a burette with some acid of known concentration. Make sure you do this BELOW EYE LEVEL — you don't want to be looking up if some acid spills over. (You should wear safety glasses too.) Record the initial volume of the acid in the burette.
- 3) Use the burette to add the acid to the alkali a bit at a time, giving the conical flask a regular swirl. Go especially slowly when you think the end-point (colour change) is about to be reached.
- 4) The indicator changes colour when all the alkali has been neutralised (e.g. phenolphthalein is pink in alkaline conditions, but colourless in acidic conditions).
- 5) Record the final volume of acid in the burette, and use it, along with the initial reading, to calculate the volume of acid used to neutralise the alkali.

Here's the Apparatus You'll Use in a Titration:

Pipette

Pipettes measure only one volume of solution. Fill the pipette to about 3 cm above the line, then drop the level down carefully to the line.

There's more about using burettes and pipettes on page 194.

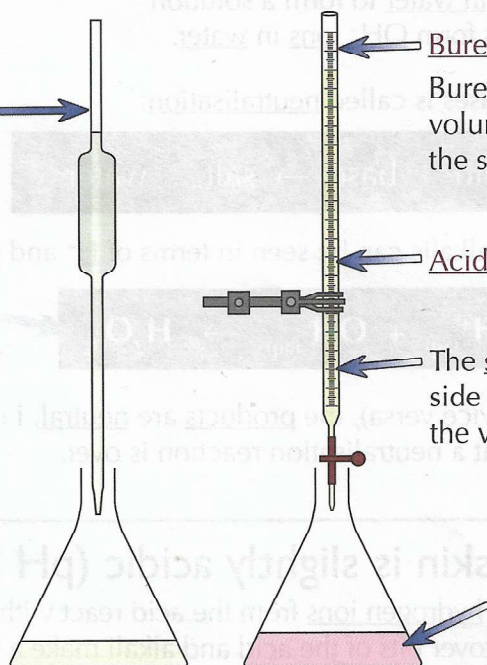
Burette

Burettes measure different volumes and let you add the solution drop by drop.

Acid (contained in the burette).

The scale (marks) down the side of the burette shows the volume of acid used.

Conical flask containing the alkali and the indicator.



Triple

Titrations

PRACTICAL

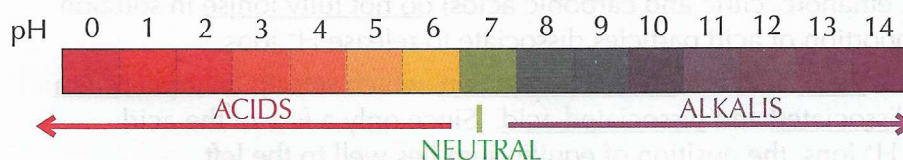
You Should Repeat Titrations and Find a Mean Volume

- 1) To increase the accuracy of your titration and to spot any anomalous results, you need several consistent readings.
- 2) The first titration you do should be a rough titration to get an approximate idea of where the solution changes colour (the end-point).
- 3) You then need to repeat the whole thing a few times, making sure you get (pretty much) the same answer each time (within 0.10 cm^3).
- 4) Finally, calculate a mean of your results, ignoring any anomalous results.

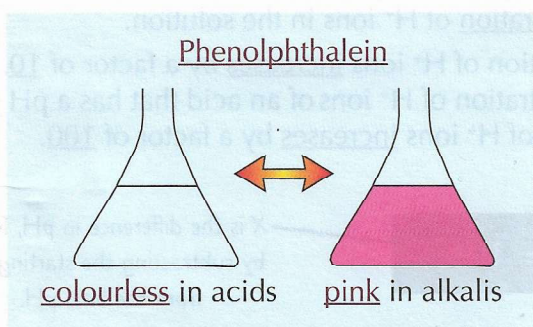
Anomalous results are ones that don't fit in with the rest (see page 7).

Use Single Indicators for Titrations

- 1) Universal indicator is used to estimate the pH of a solution because it can turn a variety of colours. Each colour indicates a narrow range of pH values.
- 2) It's made from a mixture of different indicators. The colour gradually changes from red in acidic solutions to violet in alkaline solutions.



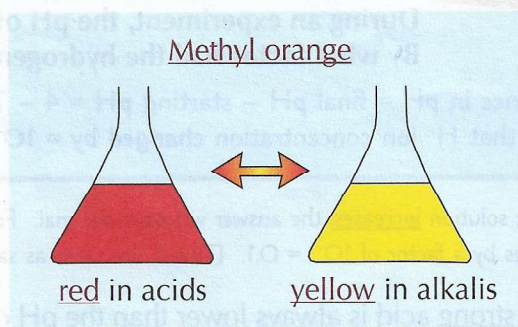
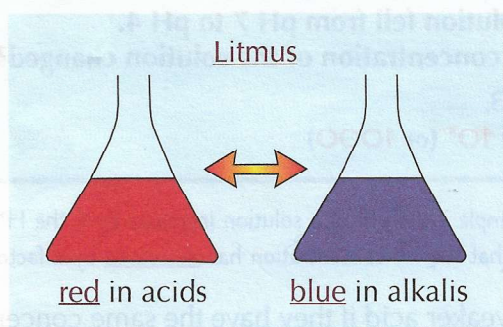
- 3) But during a titration between an alkali and an acid, you want to see a sudden colour change, at the end-point.
- 4) So you need to use a single indicator, such as:



These students are doing a titration using phenolphthalein as the indicator.



The alkali in the flask is tinted pink. (At the end-point the solution will go colourless.)



Accuracy is everything...

When you're doing a titration you need to make sure that your results are as accurate as possible. To do this you need to a) go slowly as you reach the end-point, and b) do repeats and find a mean.

Strong Acids, Weak Acids and their Reactions

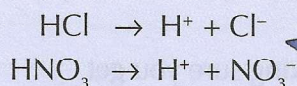
Right, it's time for strong acids versus weak acids. Brace yourself, it's not the simplest bit of chemistry ever...

Acids Produce Protons in Water

← An H^+ ion is just a proton.

The thing about acids is that they ionise in aqueous solution — they produce hydrogen ions, H^+ .

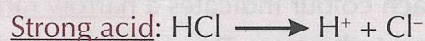
For example:



These acids don't produce hydrogen ions until they meet water. So, for example, hydrogen chloride gas isn't acidic.

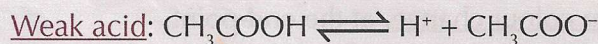
Acids Can be Strong or Weak

- 1) Strong acids (e.g. sulfuric, hydrochloric and nitric acids) ionise completely in water. All the acid particles dissociate to release H^+ ions.



- 2) Weak acids (e.g. ethanoic, citric and carbonic acids) do not fully ionise in solution. Only a small proportion of acid particles dissociate to release H^+ ions.

- 3) The ionisation of a weak acid is a reversible reaction, which sets up an equilibrium between the undissociated and dissociated acid. Since only a few of the acid particles release H^+ ions, the position of equilibrium lies well to the left.



For more on equilibria turn to p.127.

- 4) The pH of an acid or alkali is a measure of the concentration of H^+ ions in the solution.
- 5) For every decrease of 1 on the pH scale, the concentration of H^+ ions increases by a factor of 10. So, an acid that has a pH of 4 has 10 times the concentration of H^+ ions of an acid that has a pH of 5. For a decrease of 2 on the pH scale, the concentration of H^+ ions increases by a factor of 100. The general rule for this is:

Factor H^+ ion concentration changes by $= 10^{-X}$

X is the difference in pH, found by subtracting the starting pH from the final pH.

EXAMPLE:

During an experiment, the pH of a solution fell from pH 7 to pH 4.
By what factor had the hydrogen ion concentration of the solution changed?

Difference in pH = final pH – starting pH = $4 - 7 = -3$.

Factor that H^+ ion concentration changed by $= 10^{-(-3)} = 10^3$ (or 1000)

If the pH of the solution increases, the answer will be a decimal. For example if the pH of a solution increases by 1, the H^+ ion concentration changes by a factor of $10^{-1} = 0.1$. (This is the same as saying that the H^+ concentration has decreased by a factor of 10.)

- 6) The pH of a strong acid is always lower than the pH of a weaker acid if they have the same concentration.



Strong acids ionise completely, but weak acids don't

Calculating the factor that hydrogen ion concentration changes by as pH changes can be a bit tricky. The best way to get to grips with it is just to get lots of practice at using the formula.

Strong Acids, Weak Acids and their Reactions

Don't Confuse Strong Acids with Concentrated Acids

- 1) Acid strength (i.e. strong or weak) tells you what proportion of the acid molecules ionise in water.
- 2) The concentration of an acid is different. Concentration measures how much acid there is in a certain volume of water. Concentration is basically how watered down your acid is.

Concentration describes the total number of dissolved acid molecules — not the number of molecules that are ionised to produce hydrogen ions at any given moment.
- 3) The larger the amount of acid there is in a certain volume of liquid, the more concentrated the acid is.
- 4) So you can have a dilute (not very concentrated) but strong acid, or a concentrated but weak acid.
- 5) pH will decrease with increasing acid concentration regardless of whether it's a strong or weak acid.

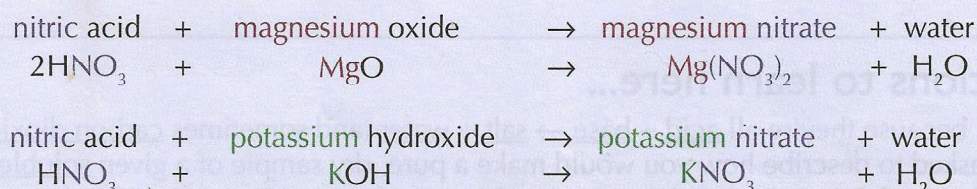
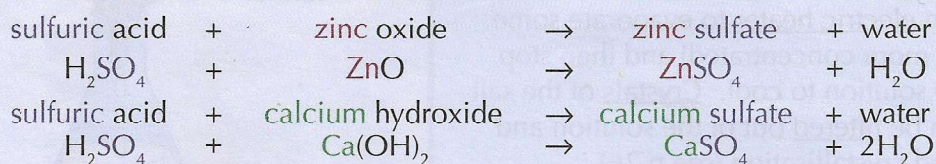
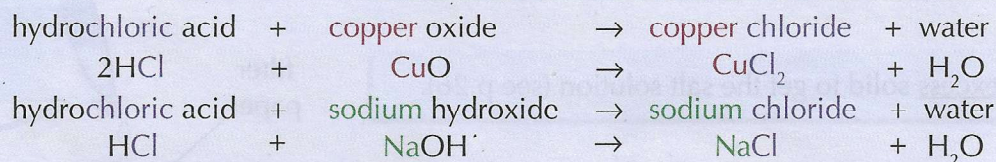
Metal Oxides and Metal Hydroxides are Bases

- 1) Some metal oxides and metal hydroxides dissolve in water. These soluble compounds are alkalis. As you saw on page 87, alkalis react with acids in neutralisation reactions.
- 2) Even bases that won't dissolve in water will still take part in neutralisation reactions with acids.
- 3) So, all metal oxides and metal hydroxides react with acids to form a salt and water.



The Combination of Metal and Acid Decides the Salt

This isn't exactly exciting, but it's pretty important, so try and get the hang of it:



To work out the formula of an ionic compound, you need to balance the charges of the positive and negative ions so the compound is neutral.

For more on formulas of ionic compounds, see p.51.

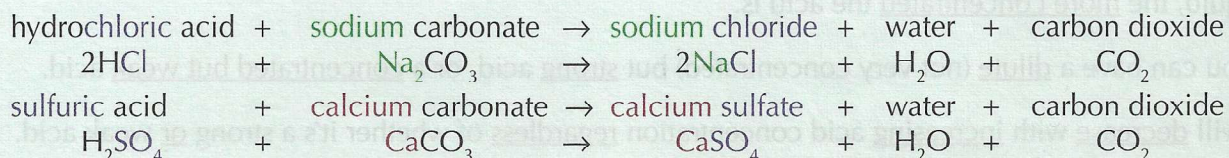
Strong Acids, Weak Acids and their Reactions

Acids and Metal Carbonates Produce Carbon Dioxide

Metal carbonates are also bases. They will react with acids to produce a salt, water and carbon dioxide.



Here are a few examples of acid and metal carbonate reactions:



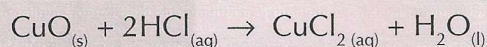
You can Make Soluble Salts Using an Insoluble Base

PRACTICAL

- 1) You need to pick the right acid, plus an insoluble base such as an insoluble hydroxide, metal oxide or carbonate.

You can also make some salts by reacting a metal with an acid (see page 95 for more).

For example, if you want to make copper chloride, you could mix hydrochloric acid and copper oxide:

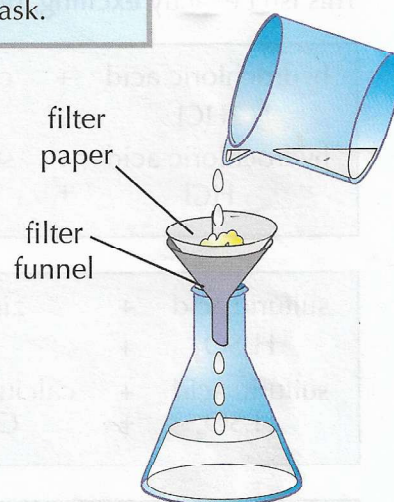


- 2) Gently warm the dilute acid using a Bunsen burner, then turn off the Bunsen burner.

- 3) Add the insoluble base to the acid a bit at a time until no more reacts (i.e. the base is in excess). You'll know when all the acid has been neutralised because, even after stirring, the excess solid will just sink to the bottom of the flask.

- 4) Then filter out the excess solid to get the salt solution (see p.26).

- 5) To get pure, solid crystals of the salt, gently heat the solution using a water bath or an electric heater to evaporate some of the water (to make it more concentrated) and then stop heating it and leave the solution to cool. Crystals of the salt should form, which can be filtered out of the solution and then dried. This is called crystallisation (see p.26).



Quite a few reactions to learn here...

...but it's not so bad really, because they're all acid + base → salt + water (and sometimes carbon dioxide). Remember, you could be asked to describe how you would make a pure, dry sample of a given soluble salt, so make sure you understand the method and that you could suggest a suitable acid and base to use.

Warm-Up & Exam Questions

So you think you know everything there is to know about acids? Time to put yourself to the test.

Warm-Up Questions

- 1) What range of values can pH take?
- 2) What term is used to describe a solution with a pH of 7?
- 3) What's the difference between a strong acid and a weak acid?
- 4) If the pH of the solution rises from 2 to 5, what factor has the hydrogen ion concentration of the solution changed by?
- 5) Name the two substances formed when nitric acid reacts with copper hydroxide.

Exam Questions

- 1 A student had a sample of acid in a test tube. He gradually added some alkali to the acid. Grade 4-6

- 1.1 Name the type of ion that acids produce in aqueous solutions. [1 mark]

- 1.2 What type of reaction took place in the student's experiment? Tick **one** box.

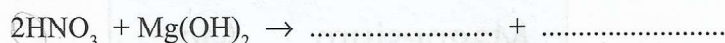
☐ thermal decomposition ☐ neutralisation ☐ redox ☐ combustion

[1 mark]

- 2 All metal hydroxides are bases. They can react with acids to form a salt and water. Grade 6-7

- 2.1 Sodium hydroxide is a soluble base. What name is given to bases that dissolve in water? [1 mark]

- 2.2 Complete and balance the symbol equation given below for the reaction of nitric acid with magnesium hydroxide.



[2 marks]

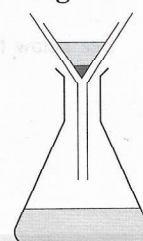
PRACTICAL

- 3 Silver nitrate is a soluble salt. It can be made by adding an excess of insoluble silver carbonate to nitric acid until no further reaction occurs. Grade 6-7

- 3.1 Give **one** observation that would indicate that the reaction is complete. [1 mark]

- 3.2 Once the reaction is complete, the excess silver carbonate can be separated from the silver nitrate solution using the apparatus shown in **Figure 1**. What is this method of separation called? [1 mark]

Figure 1



- 3.3 Describe how you could produce solid silver nitrate from silver nitrate solution. [3 marks]

PRACTICAL

- 4* Describe the method you would use to carry out an accurate titration to find the volume of acid needed to neutralise 25.0 cm³ of an alkali. Assume you have already done a rough titration. Grade 6-7

[6 marks]

Metals and their Reactivity

Metals can be placed in order of reactivity. This can be really useful for predicting their reactions.

The Reactivity Series — How Well a Metal Reacts

- 1) The reactivity series lists metals in order of their reactivity towards other substances.
- 2) For metals, their reactivity is determined by how easily they lose electrons — forming positive ions. The higher up the reactivity series a metal is, the more easily it will form positive ions.
- 3) When metals react with water or acid, they lose electrons and form positive ions. So, the higher a metal is in the reactivity series, the more easily it reacts with water or acid.
- 4) If you compare the relative reactivity of different metals with either an acid or water and put them in order from the most reactive to the least reactive, the order you get is the reactivity series.

Make sure you learn this list.

The Reactivity Series		
Potassium	K	Very Reactive
Sodium	Na	
Lithium	Li	
Calcium	Ca	
Magnesium	Mg	Fairly Reactive
Carbon	C	
Zinc	Zn	
Iron	Fe	
Hydrogen	H	Not very Reactive
Copper	Cu	

See below for more. →

See below for more. →

Carbon and Hydrogen

Carbon and hydrogen are non-metals, but they're often included in the reactivity series, because this gives you information about how metals will react with them:

- Metals that are less reactive than carbon can be extracted from their ores by reduction with carbon (see p.96). Metals that are more reactive than carbon cannot be extracted in this way.
- Metals that are more reactive than hydrogen (above it in the reactivity series) will react with acids. Metals less reactive than hydrogen will not react with acids.

Metals and their Reactivity

How Metals React With Acids Tells You About Their Reactivity

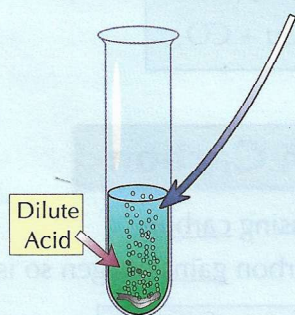
Some metals react with acids to produce a salt and hydrogen gas.



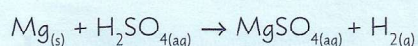
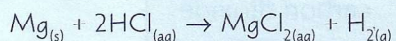
Hydrochloric acid will react to form chloride salts and sulfuric acid will react to form sulfate salts.

- 1) The speed of reaction is indicated by the rate at which the bubbles of hydrogen are given off.
- 2) The more reactive the metal, the faster the reaction will go. Very reactive metals like potassium, sodium, lithium and calcium react explosively, but less reactive metals such as magnesium, zinc and iron react less violently. In general, copper won't react with cold, dilute acids.

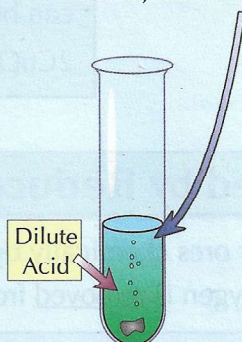
Magnesium reacts vigorously with cold dilute acids like $\text{HCl}_{(\text{aq})}$ and $\text{H}_2\text{SO}_{4(\text{aq})}$ and produces loads of bubbles.



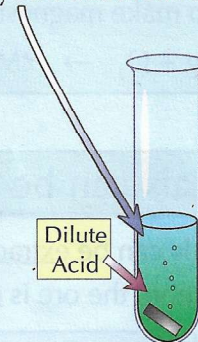
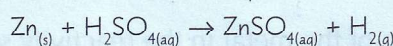
magnesium



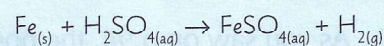
Both zinc and iron react fairly slowly with dilute acids, but more strongly if you heat them up.



zinc



iron



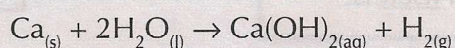
You can use the burning splint test (see page 153) to confirm that hydrogen is formed in these reactions.

Metals Also React with Water

The reactions of metals with water also show the reactivity of metals.



For example, calcium:



- 1) The metals potassium, sodium, lithium and calcium will all react with water.
- 2) Less reactive metals like zinc, iron and copper won't react with water.

You can see more on the reactions of Group 1 metals with water on page 40.

Metals at the top of the reactivity series are highly reactive

You can use the results of experiments like these to work out an order of reactivity for the metals that you used. Just remember, the more vigorous the reaction with acid or water, the more reactive the metal.

Metals and their Reactivity

Metals Often Have to be Separated from their Oxides

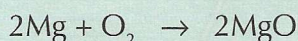
- 1) Most metals aren't found in the earth in their pure form. They tend to be fairly reactive, so they're usually found as compounds and have to be extracted before they can be used.
- 2) Lots of common metals, like iron and aluminium, react with oxygen to form their oxides, which are found in the ground. This process is an example of oxidation. These oxides are often the ores that the metals need to be extracted from.
- 3) A reaction that separates a metal from its oxide is called a reduction reaction.

An ore is a type of rock that contains metal compounds.

Formation of Metal Ore:

Oxidation = Gain of Oxygen

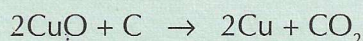
For example, magnesium can be oxidised to make magnesium oxide.



Extraction of Metal:

Reduction = Loss of Oxygen

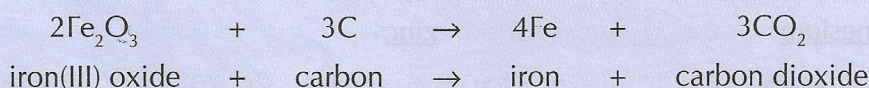
For example, copper oxide can be reduced to copper.



Some Metals can be Extracted by Reduction with Carbon

- 1) Some metals can be extracted from their ores chemically by reduction using carbon.
- 2) In this reaction, the ore is reduced as oxygen is removed from it, and carbon gains oxygen so is oxidised.

For example:



- 3) As you saw on p.94, the position of the metal in the reactivity series determines whether it can be extracted by reduction with carbon.

- Metals higher than carbon in the reactivity series have to be extracted using electrolysis, which is expensive.
- Metals below carbon in the reactivity series can be extracted by reduction using carbon. For example, iron oxide is reduced in a blast furnace to make iron. This is because carbon can only take the oxygen away from metals which are less reactive than carbon itself is.

Extracted by using electrolysis.

Extracted by reduction with carbon.

The Reactivity Series

Potassium	K	more reactive
Sodium	Na	
Lithium	Li	
Calcium	Ca	
Magnesium	Mg	
<u>CARBON</u>	<u>C</u>	
Zinc	Zn	less reactive
Iron	Fe	
Hydrogen	H	
Copper	Cu	

A few metals are so unreactive that they are found in the earth as the metal itself. For example, gold is mined as its elemental form.



Carbon can't reduce things that are above it in the reactivity series

Make sure you understand the difference between reduction and oxidation and make sure that you can spot which substance has been reduced and which substance has been oxidised in a reaction.