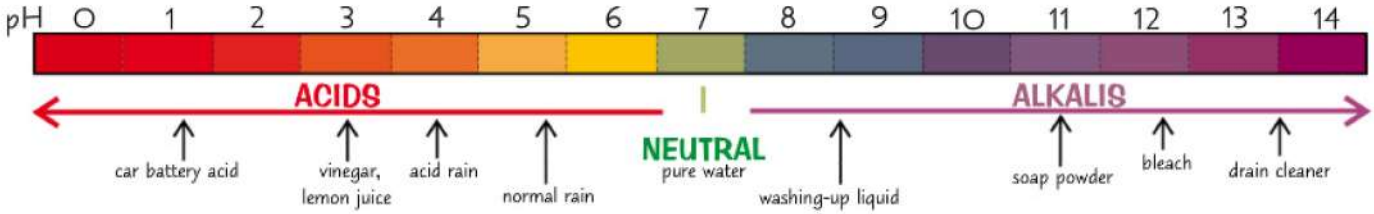
Acids and Bases

Testing the pH of a solution means using an indicator — and that means pretty colours...

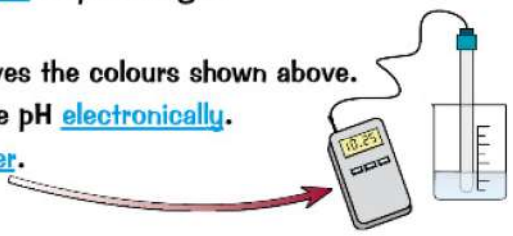
The pH Scale Goes From 0 to 14

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.
3) The higher the pH of a solution, the more alkaline it is.
4) 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.
2) Wide range indicators are substances that gradually change colour as pH changes.
3) They're useful for estimating the pH of a solution.
4) For example, Universal indicator is a wide range indicator. It gives the colours shown above.
5) A pH probe attached to a pH meter can also be used to measure pH electronically.
6) The probe is put in the solution and the pH is shown as a number. This means it's more accurate than an indicator.



Acids and Bases Neutralise Each Other

1) When acids dissolve in water, they form solutions with a pH of less than 7. Acids form H^+ ions in water.
2) Bases have pHs greater than 7.
3) Alkalis are bases that dissolve in water to form solutions with a pH greater than 7. Alkalis form OH^- ions in water. For example, soluble metal hydroxides are alkalis.

- The reaction between acids and bases is called neutralisation:

$$\text{acid} + \text{base} \rightarrow \text{salt} + \text{water}$$

- Neutralisation between acids and alkalis can be shown using H^+ and OH^- ions like this:

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

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

- The products of neutralisation reactions have a pH of 7. This means they're neutral.

4) You can add an indicator to the acid or alkali you're neutralising. Then gradually add the other substance. The indicator will change colour when the neutralisation reaction is over.
5) If you use Universal indicator, add the substance until the Universal indicator is green. This is when the pH of the solution is neutral.

This page should have all bases covered...

pHew, you finished the page... So here's an interesting(ish) fact about pH — your skin is slightly acidic (pH 5.5).

Q1 What colour would you expect Universal indicator to turn if you added it to lemon juice? [1 mark]

Q2 The pH of a solution is 8. Is the solution acidic or alkaline? [1 mark]

Reactions of Acids

Remember neutralisation reactions from the previous page? Well, there's more about them coming up...

Metal Oxides and Metal Hydroxides are Bases

1) Metal oxides and metal hydroxides react with acids in neutralisation reactions to form a salt and water.
2) The salt that forms depends upon the acid and the metal ion in the oxide or hydroxide.
3) HCl reacts to form chlorides, H_2SO_4 reacts to form sulfates and HNO_3 reacts to form nitrates.

hydrochloric acid	+	copper oxide	→	copper chloride	+	water
$2HCl$	+	CuO	→	$CuCl_2$	+	H_2O
sulfuric acid	+	potassium hydroxide	→	potassium sulfate	+	water
H_2SO_4	+	$2KOH$	→	K_2SO_4	+	$2H_2O$
nitric acid	+	sodium hydroxide	→	sodium nitrate	+	water
HNO_3	+	$NaOH$	→	$NaNO_3$	+	H_2O

Acids and Metal Carbonates Produce Carbon Dioxide

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

hydrochloric acid	+	sodium carbonate	→	sodium chloride	+	water	+	carbon dioxide
$2HCl$	+	Na_2CO_3	→	$2NaCl$	+	H_2O	+	CO_2
sulfuric acid	+	calcium carbonate	→	calcium sulfate	+	water	+	carbon dioxide
H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	H_2O	+	CO_2

You can Make Soluble Salts Using an Insoluble Base

PRACTICAL

1) If you react an acid with an insoluble base or a metal, you can make a soluble salt.
2) First, pick the acid that contains the same negative ion as the salt you want to make. For example, to make copper chloride, you'd choose hydrochloric acid.
3) Then pick an insoluble base with the same positive ion as the salt you want to make. You could use an insoluble metal oxide, hydroxide, or carbonate.
4) So to make copper chloride, you'd choose copper oxide, copper hydroxide or copper carbonate. Here's the equation for making copper chloride from hydrochloric acid and copper oxide:

$$CuO_{(s)} + 2HCl_{(aq)} \rightarrow CuCl_{2\,(aq)} + H_2O_{(l)}$$

5) Gently warm the dilute acid using a Bunsen burner, then turn off the Bunsen burner.
6) Add the insoluble base to the acid until no more reacts (you'll see the solid at the bottom of the flask).
7) Filter out the solid that hasn't reacted to get the salt solution (see p.102).
8) To get pure, solid crystals of the salt, you need to crystallise it (see p.102).
9) To do this, gently heat the solution using a water bath or an electric heater. Some of the water will evaporate. Stop heating the solution and leave it to cool.
10) Crystals of the salt should form, which can be filtered out of the solution and then dried.

AHHHHH so many reactions...

There might be lots of reactions on this page, but I've treated you to a nice experiment as well. You're welcome.

Q1 Write a word equation for the reaction between calcium carbonate and hydrochloric acid. [2 marks]

The Reactivity Series and Extracting Metals

You can place metals in order of reactivity. This can be a lot more useful than it sounds, promise.

The Reactivity Series — How Easily a Metal Reacts

1) The reactivity series lists metals in order of how reactive they are (their reactivity).
2) Metals react to form positive ions.
3) So for metals, their reactivity depends on how easily they lose electrons and form positive ions.
4) The higher up the reactivity series a metal is, the more easily it forms positive ions.

Carbon and hydrogen are non-metals but are often included in 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	

Metals Often Have to be Separated from their Oxides

1) Lots of common metals, like iron and aluminium, react with oxygen to form oxides.
2) This process is an example of oxidation.
3) These oxides are often the ores that the metals are removed (extracted) from.
4) 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. Most metals are found in the earth as ores.

Oxidation = Gain of Oxygen

E.g. magnesium is oxidised to make magnesium oxide.

$2Mg + O_2 \rightarrow 2MgO$

Reduction = Loss of Oxygen

E.g. copper oxide is reduced to copper.

$2CuO + C \rightarrow 2Cu + CO_2$

Some Metals can be Extracted by Reduction with Carbon

1) Some metals can be extracted from their ores using a reaction with carbon.
2) In this reaction, the ore is reduced as oxygen is removed from it. Carbon gains oxygen, so it is oxidised.
3) For example: iron(III) oxide + carbon → iron + carbon dioxide $\quad 2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

Iron has lost oxygen. Carbon has gained oxygen.

4) The reactivity series can tell you if a metal can be extracted with carbon.

- Metals above carbon in the reactivity series are extracted using electrolysis (p.132). This is expensive as it takes lots of energy to melt the ore and to produce the electricity.
- Electrolysis is also used to extract metals that react with carbon.
- 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.

Make sure you can explain how and why different metals are extracted in different ways.

5) Some metals are so unreactive they are found in the earth as the metal itself. For example, gold.

Are you going to revise this page, ore what?

From the metals in the reactivity series above, only zinc, iron and copper can be extracted with carbon.

Q1 A mining company tried to extract calcium from calcium oxide by reduction with carbon. The process did not work. Explain why. [1 mark]

Reactions of Metals

Metals react to form salts. And you, my friend, need to be able to predict the salt that'll form from a reaction.

Metals React With Acids

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

Acid + Metal → Salt + Hydrogen

HCl reacts to form chloride salts, H_2SO_4 reacts to form sulfate salts.

• hydrochloric acid + magnesium → magnesium chloride + hydrogen	$2HCl + Mg \rightarrow MgCl_2 + H_2$
• sulfuric acid + zinc → zinc sulfate + hydrogen	$H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$
• hydrochloric acid + iron → iron chloride + hydrogen	$2HCl + Fe \rightarrow FeCl_2 + H_2$

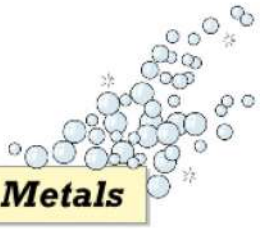
2) Very reactive metals like potassium, sodium, lithium and calcium react explosively with acids.
3) Less reactive metals such as magnesium, zinc and iron react less violently with acids.
4) In general, copper won't react with cold, dilute acids.

Metals Also React with Water

1) Many metals will also react with water.

Metal + Water → Metal Hydroxide + Hydrogen

2) For example, calcium: $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
3) The metals potassium, sodium, lithium and calcium will all react with water.
4) Less reactive metals like zinc, iron and copper won't react with water.



You Can Work Out a Reactivity Series from the Reactions of Metals

1) If you put metals in order from most reactive to least reactive based on their reactions with either an acid or water, the order you get is the reactivity series (see the previous page).
2) To compare the reactivities of metals, you could watch how quickly bubbles of hydrogen are formed in their reactions with water or acid. The more reactive the metal, the faster the bubbles will form.
3) You can also measure the temperature change of the reaction in a set time period. The more reactive the metal, the greater the temperature change should be.

For these experiments to be fair, the mass and surface area of the metals should be the same each time.

More Reactive Metals can Displace Less Reactive Metals from Salts

1) Displacement reactions involve one metal kicking another one out of a compound. Here's the rule:

A MORE REACTIVE metal will displace a LESS REACTIVE metal from its compound.

2) For example, iron is more reactive than copper. So if you add solid iron to copper sulfate solution, you get a displacement reaction.
3) The iron kicks the copper out of copper sulfate. You end up with iron sulfate solution and copper solid.

iron + copper sulfate → iron sulfate + copper $\quad Fe_{(s)} + CuSO_{4(aq)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$

New information displaces old information from my brain...

See, experiments aren't just for fun — they can give you a thrilling insight into the relative reactivities of elements.

Q1 Complete the word equation for the reaction of sodium and water: sodium + water → ? + ? [2 marks]