Reactions of metals and metal compounds

Before starting this unit, you should already be familiar with these ideas from earlier work.

- Metals are elements that have particular properties. One is that they conduct heat well. What other properties do metals share?
- In a chemical reaction, atoms join up in different ways.
- We use symbols with one or two letters to represent elements. What are the symbols for copper and carbon?
- When atoms are joined, we combine symbols into formulae. Can you remember what $CuSO_4$ stands for? (Hint: It's blue!)
- We describe chemical reactions in several ways – word equations, particle equations and symbol equations.
- If a gas is given off in a reaction, we can test it to see what it is. Can you remember the tests for hydrogen and carbon dioxide?
- In a neutralisation reaction, an acid is cancelled out. What sort of chemical neutralises an acid?

You will meet these key ideas as you work through this unit. Have a quick look now, and at the end of the unit read them through slowly.

- In a chemical reaction reactants are used up, and new products form. There might be a colour change, or bubbles. Another sign of a chemical reaction is energy transfer. Flashes, bangs and breaking glassware suggest that energy is given out!
- In chemical reactions, the atoms become rearranged. This can help you work out what the products might be. For example, if you heat copper in a gas jar of oxygen, and a reaction happens, what could be formed? There are not too many possibilities . . .
- You can use this idea of rearranged atoms to predict what might be formed in a reaction. Writing symbols and formulae helps.
- Because a chemical reaction is just a rearrangement of the atoms, the total mass of product is the same as the total mass of reactant. Mass is conserved in chemical reactions.
- Acids react with some metals. A salt is formed in these reactions, along with hydrogen gas.
- Acids also react with metal carbonates and with metal oxides to form a salt.

9E.1

Metals

A

Why are metals useful?

Metals are elements

Do you remember how elements are organised in the periodic table? **Metals** are elements on the left-hand side of the table. Metals are usually shiny, hard and feel cold to the touch. **Non-metals** are elements on the right-hand side of the periodic table. Non-metals are usually dull, softer and do not feel cold to the touch.

																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra																

key: metals, non-metals

Remember

Sulphur is a non-metal – it is an element on the right-hand side of the periodic table. Plastic, wood and concrete are not metals, but they are not non-metal elements either. They contain compounds, so you won't find them in the periodic table.

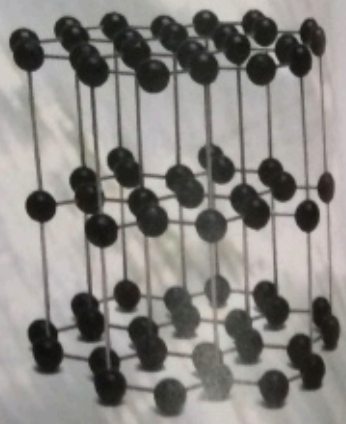
Properties of metals and non-metals

Metals	Non-metals
conduct heat well	most conduct heat poorly
conduct electricity well	most conduct electricity poorly
strong	not as strong as metals
hard	softer than metals
very flexible – can be shaped and drawn into wires (ductile)	brittle – may shatter if you hit them
sonorous – make a noise like a bell when you hit them	not sonorous
shiny (though some may tarnish)	usually dull in appearance
high melting and boiling point	low melting and boiling point
dense	not very dense
iron, nickel and cobalt are magnetic	not magnetic

Some exceptions to the rule

Some metals and non-metals are a bit different. They do not follow the general properties shown in the table.

Graphite is a form of the non-metal element carbon. Graphite is shiny and it can conduct electricity, unusual for a non-metal. The layers of carbon atoms allow charge to pass through its structure.



In graphite the carbon atoms are arranged in layers, as the model shows.

Diamond is also a form of carbon. In spite of being a non-metal diamond is the hardest natural material known. Its structure makes it very strong so it is used to tip drills and cutting tools.

Mercury is a metal element. It has a low melting point which makes it the only metal that is a liquid at room temperature.

Mercury is liquid metal.

How do we use metals?

The properties of metals make them useful in all sorts of ways.

Iron is strong and also quite cheap so we use it for bridges and buildings.

Titanium is light but strong. It is also very expensive.

Where do metals come from?

Most metals are found in the ground not as the pure metal but combined in a compound – usually the oxide or sulphide. A mineral that contains a metal is called an **ore**. The table shows some ores.

Metal ore	Main compound in ore
haematite	iron oxide
zinc blende	zinc sulphide
malachite	copper carbonate
galena	lead sulphide

We dig out the ore and then extract the metal from it. A chemical reaction splits the metal from the ore. (You will find out more about this on page 77.) Metals are extracted from their ores in different ways.

- **Smelting**: roast (melt) the ore with carbon. Iron and zinc are extracted like this.
- **Electrolysis**: pass electricity through the melted ore or a solution of the ore. Aluminium is extracted by electrolysis.
- **Displacement**: react the metal ore with a more reactive metal. Titanium is extracted this way.

1 Copy and complete using words from the Language bank:

Metals are good _____ of heat and electricity while most non-metals are poor conductors. Metals are found on the left-hand side of the _____ while non-metals are found on the right.

2 Why is rubber neither a metal nor a non-metal?

3 Working in a group, each choose a different metal to research. Find out as much as you can about the metal:

- What are its properties?
- How is it used?
- How do the properties make it useful in this way?
- Where do we find the ore?

Then build up a database of all the information the class found.

Language bank

compounds
conductors
diamond
displacement
electrolysis
elements
graphite
mercury
metal
non-metal
ore
periodic table
properties
smelting

9E.2 Metals and acids

M

- What happens when metals react with acids?

Bubbling away

Zinc reacts with both hydrochloric acid (left) and sulphuric acid (right).

Zinc, like many other metals, reacts with acids. Do you remember the signs that tell you a chemical reaction is happening? You know the zinc is reacting with the acid because:

- you can see bubbles of gas, a new material being formed
- the pieces of zinc become smaller
- the tube gets warm as heat is given out – energy is transferred
- if you evaporate the liquid left at the end of the reaction, it leaves a white solid called a salt, another new material.

These salts are produced in the reactions.

What are the products?

Zinc reacts with acid to give off a gas and produce a salt. We can test the gas to see what it is. This reaction produces hydrogen gas.

Remember

The test for hydrogen is the squeaky pop test. The test for carbon dioxide is that it turns limewater cloudy.

Looking at the particles

When zinc reacts with acids the particles are rearranged:

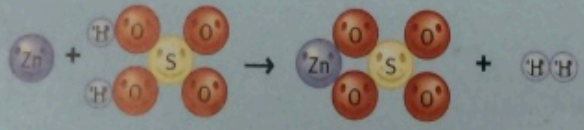
Word equation: zinc + hydrochloric acid → zinc chloride + hydrogen

Symbol equation: $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

The zinc takes the place of the hydrogen in the acid to make the salt and hydrogen.

Word equation: zinc + sulphuric acid → zinc sulphate + hydrogen

Symbol equation: $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

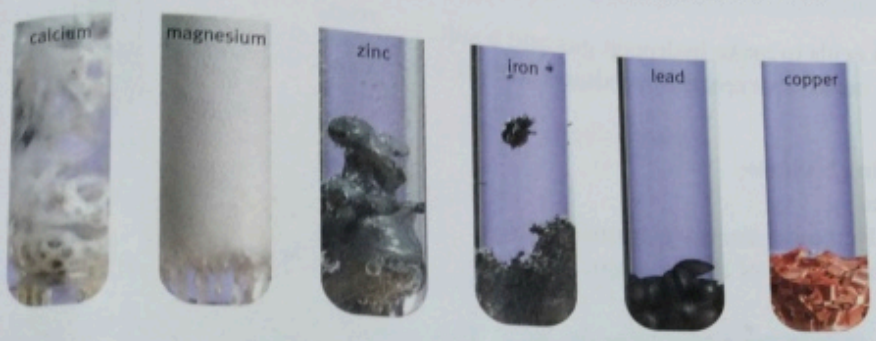


The zinc takes the place of the hydrogen in the acid to make the salt and hydrogen.

You can see how new materials are formed when the particles are rearranged in these chemical reactions. No new particles are added, so the total mass stays the same.

Patterns in the reactions

Many other metals react with acids like zinc does. But some metals do not react with acids.



The metals all react slightly differently. **Reactive** metals like calcium and magnesium bubble and fizz quite violently. Other metals like zinc and iron bubble away steadily. Metals that are less reactive than copper do not react with dilute acids.

We can write a general equation for the reaction of metals with acids:

metal + acid → salt + hydrogen

If a metal reacts with acid, this equation shows how it reacts.

A reactivity pattern

Some metals react more violently with acids than others. If we look at how metals react, we can list them in order of reactivity. We call this list the **reactivity series** or **activity series**. It is shown opposite.

Guess what?

Have you ever tried putting a penny in a cola drink for a day or two? The phosphoric acid and carbonic acid in the drink react with the dull coating and clean it up.

Reactivity series

sodium (Na)
calcium (Ca)
magnesium (Mg)
aluminium (Al)
zinc (Zn)
iron (Fe)
lead (Pb)
(hydrogen (H))
copper (Cu)
silver (Ag)
gold (Au)

If a metal is below hydrogen it will not react with dilute acids.

1 Copy and complete using words from the Language bank:
Some metals react with dilute acids like _____ and _____. A _____ and hydrogen gas are formed. The most _____ metals react the most violently.

2 What is the test for hydrogen gas?

3 Write the general equation for a metal reacting with an acid.

4 Write a word equation for:
a magnesium reacting with sulphuric acid
b iron reacting with hydrochloric acid.

5 Predict whether silver will react with dilute hydrochloric acid. Explain your answer.

6 Write symbol equations for the reactions in question 4.

Language bank

activity series
general equation
hydrochloric acid
hydrogen
reactive
reactivity series
salt
sulphuric acid

9E.3

Metal carbonates and acids

M

- How do acids react with metal carbonates?

More bubbling reactions

You know that metals react with acids to make hydrogen gas and a salt. Metal carbonates also react with acids. This reaction produces carbon dioxide gas, a salt and water.

You can tell a reaction is happening because:

- a gas is formed – a new material
- the tube gets warm as heat is given out – energy is transferred
- if you evaporate the liquid left at the end of the reaction, it leaves a salt – another new material.

When magnesium carbonate reacts with sulphuric acid, the temperature rises.

Here is a word equation for the reaction:

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

We can write this general equation:

metal carbonate + acid → salt + carbon dioxide + water

Looking at the particles

Looking at the particles can help us work out what rearrangements are going on in the reaction. The table shows some particle pictures.

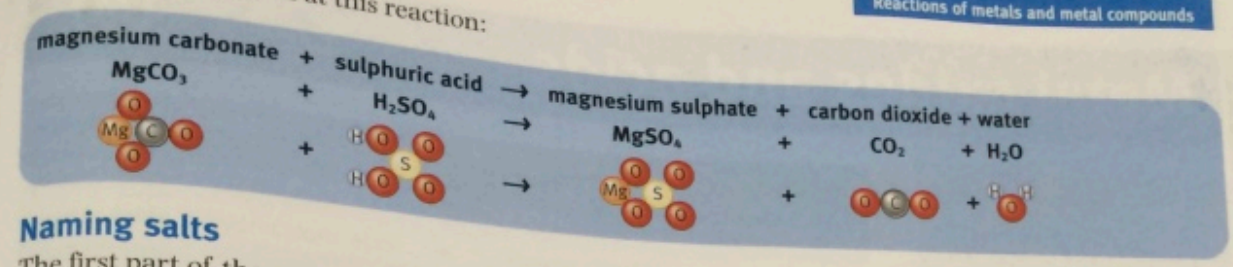
Substance	Particle picture	Formula
magnesium carbonate		$MgCO_3$
calcium carbonate		$CaCO_3$
sodium carbonate		Na_2CO_3
hydrochloric acid		HCl
sulphuric acid		H_2SO_4
nitric acid		HNO_3
water		H_2O
carbon dioxide		CO_2
hydrogen		H_2

This acid and carbonate stuff sounds complicated – is it any use?

Think about acid rain and limestone rock.

Acid rain is gradually destroying many ancient buildings made of limestone.

Let's take a closer look at this reaction:



Magnesium takes the place of hydrogen in the acid to form the salt magnesium sulphate. The carbonate part splits. It forms carbon dioxide, and loses an oxygen. Hydrogen joins with this oxygen to make water.

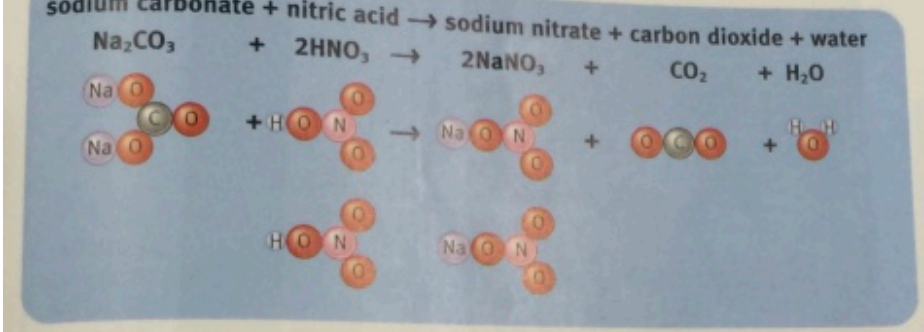
Naming salts

The first part of the name comes from the metal.

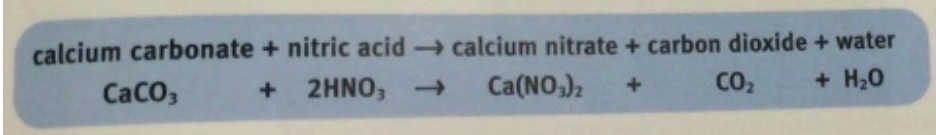
The acid you use gives the second part of the salt's name:

- sulphuric acid makes **sulphates**
- hydrochloric acid makes **chlorides**
- nitric acid makes **nitrates**.

This reaction forms the salt sodium nitrate:



If we used calcium carbonate instead, the salt would be calcium nitrate. Carbon dioxide and water are also produced as before.



1 Copy and complete using words from the Language bank:
Acids react with _____ to produce a salt, _____ and water. When this happens the _____ rises, showing that energy is transferred.

2 Write a general equation showing how an acid reacts with a metal carbonate.

3 Using the pictures above, draw the particles in the reaction between zinc carbonate ($ZnCO_3$) and sulphuric acid.

Guess what?

Symbols and formulae are used all over the world, so scientists who speak different languages can understand each other's work.

Language bank

carbon dioxide
chloride
metal carbonates
nitrate
sulphate
temperature
water

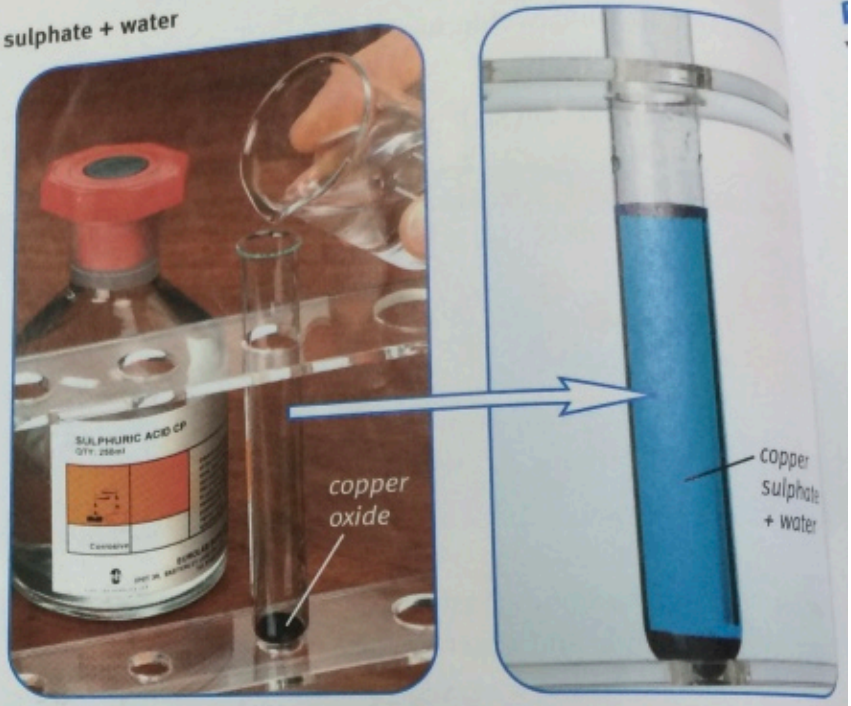
9E.4 Metal oxides and acids

- What evidence is there of a chemical reaction between acids and metal oxides?

Another acid reaction

Copper oxide is a black powder. It reacts with sulphuric acid to make copper sulphate (a salt) and water.

sulphuric acid + copper oxide → copper sulphate + water



You can tell a reaction is happening because:

- the colour changes
- if you evaporate the blue solution you get crystals of copper sulphate, a new material
- the tube gets warm as heat is given out – energy is transferred.

There are no bubbles this time because no gas is produced.

Acids react with many metal oxides to make a salt and water. Here is the general equation for the reaction:

metal oxide + acid → salt + water

Back to bases

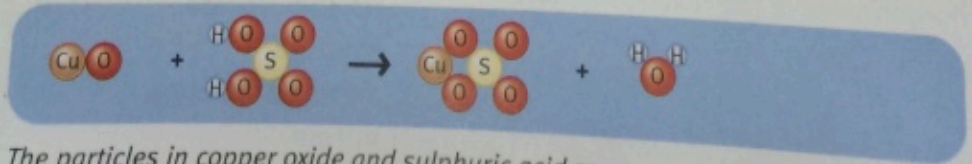
A metal oxide is a **base**. Bases are substances that make a salt and water when they react with an acid. A soluble base is called an **alkali**. You have studied neutralisation reactions between alkalis and acids.

Looking at the particles

You can see how the particles are rearranged in this reaction:

copper oxide + sulphuric acid → copper sulphate + water

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$



The particles in copper oxide and sulphuric acid rearrange themselves to make copper sulphate and water in this neutralisation reaction.

Which salt?

- The metal in the oxide gives the first part of the salt's name.
- The acid gives the ending of the name.

Metal oxide	Acid		Salt	Other product
copper oxide	sulphuric acid	→	copper sulphate	water
copper oxide	hydrochloric acid	→	copper chloride	water
copper oxide	nitric acid	→	copper nitrate	water

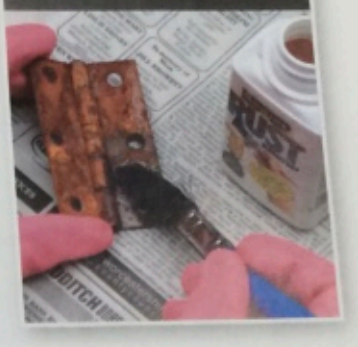
Remembering neutralisation and pH

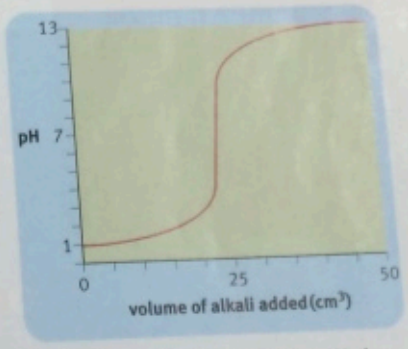
When an acid and an alkali react, they neutralise each other. The pH of the acid is 1 at the start, and the pH of the alkali is 14. At the end, the mixture is neutral, pH 7.

We can monitor the pH of a neutralisation reaction using a pH probe connected to a data logger. In this reaction acid is being added to alkali, so the pH is falling.

Guess what?

Rust is a base and rust remover contains an acid. So removing rust is a neutralisation reaction.





If alkali is added to acid, the pH rises instead.

1 Copy and complete using words from the Language bank:
An acid reacts with a _____ producing a _____ and water. The _____ is a new material, evidence that this is a _____.

2 Write the general equation for a reaction between an acid and a metal oxide.

3 Write a word or symbol equation for the reaction of zinc oxide with:
a hydrochloric acid **b** sulphuric acid **c** nitric acid.
The formula for zinc oxide is ZnO.

Language bank

chemical reaction
data logger
metal oxide
neutralisation
pH
salt

9E.5

What exactly is a salt?

S

What is a salt?

When you say 'salt' you probably think of the white stuff you put on chips. But that is just one salt, called common salt or sodium chloride. There are many others.

Salts are made in all these reactions:

metal + acid → salt + hydrogen
base + acid → salt + water
metal carbonate + acid → salt + carbon dioxide + water

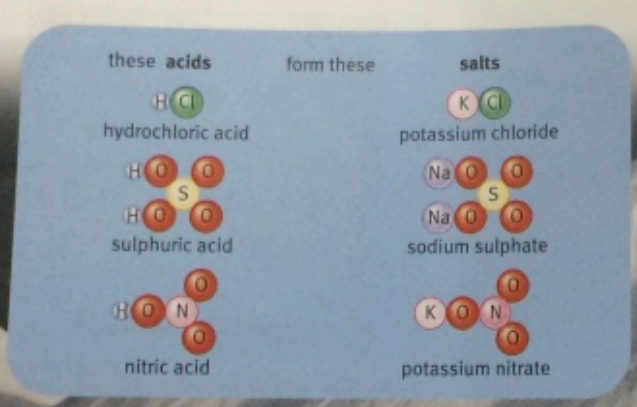
Think of a salt as an acid with its hydrogen replaced by a metal:

potassium chloride

came from the metal, base or carbonate — came from hydrochloric acid

Remember
Bases include some metal oxides and metal hydroxides.
An alkali is a soluble base.

These piles of sodium chloride have been extracted from the sea



What would we do without salts?

Common salt (table salt) is sodium chloride. As well as making food tasty, sodium chloride is a major part of the world's oceans. In your body sodium chloride and other salts are kept in balance so your cells work properly.

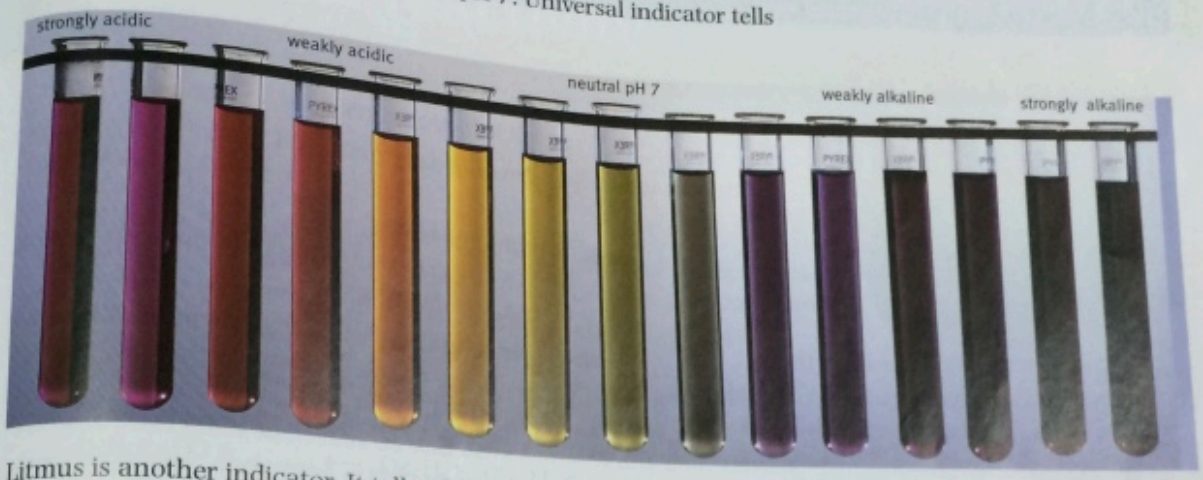
Eating too much salt is bad for your health. Low sodium salt contains potassium chloride instead of sodium chloride for people who want to reduce their sodium intake. Sea salt contains sodium iodide among other salts.

Plaster of Paris is used to set a broken arm. It is made from magnesium sulphate.

If you have greenfly on your prize plants you might spray them with greenfly killer containing copper sulphate.

pH tells us how acidic

You know that an acid has a pH lower than 7. An alkali has a pH higher than 7. A neutral solution has pH 7. Universal indicator tells us the pH of a solution.



Litmus is another indicator. It tells whether a solution is acidic or alkaline, but not *how* acidic or alkaline.

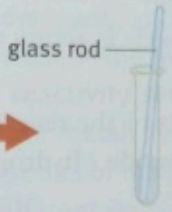
Remember
Acids and alkalis can be corrosive, harmful or irritant. Be careful with them and always wear goggles.

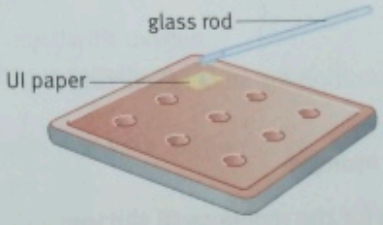
Using universal indicator to check neutralisation

On page 63 you saw how we can use a data logger to follow a neutralisation reaction. Another method is to use universal indicator paper instead.

If you add alkali to acid bit by bit, you can test the pH after each addition to check whether it is neutral yet.

add alkali to acid a little at a time





test pH of solution by dropping some onto universal indicator paper

When the solution is neutralised you can evaporate off the water to leave the salt behind.

1 Copy and complete using words from the Language bank:
When you add an alkali to an acid a _____ reaction happens. When it is complete the pH will be pH 7. You can check this with _____ .

2 **a** What is a salt?
b Give one way of making a salt.

3 With an adult's permission, look through the labels on food and medicines at home. List all the salts that you find.

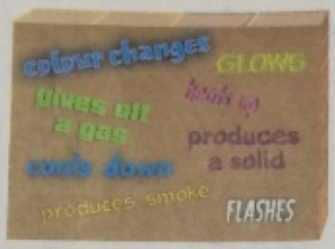
4 Find out what these salts are used for.
a iron sulphate **b** silver nitrate **c** calcium phosphate

Language bank

acid
alkali
base
neutralisation
pH
salt
universal indicator

Checkpoint

1 Evidence of a chemical reaction



This word wall shows some signs that a chemical reaction is happening. Which of them are evidence of energy being transferred in the reaction?

2 Working it out

Look at these word equations. Copy and complete them. For each one, you can rearrange the reactants to work out what the products are.

a magnesium + oxygen ⟶

b sodium carbonate + iron chloride ⟶

c iron + sulphur ⟶

d zinc + copper sulphate ⟶

3 Word equations

Here is the general equation for an acid reacting with a metal:

metal + acid ⟶ salt + hydrogen

Write word equations for the reactions at the top of the next column.

a magnesium with hydrochloric acid

b zinc with sulphuric acid

c calcium with nitric acid

d iron with sulphuric acid

4 Symbol equations

Here is the general equation for an acid reacting with a metal carbonate:

acid + metal carbonate ⟶ salt + carbon dioxide + water

Copy and complete these symbol equations.

a $CuCO_3 + 2HCl \longrightarrow CuCl_2 + \_\_\_\_ + H_2O$

b $MgCO_3 + H_2SO_4 \longrightarrow \_\_\_\_ + CO_2 + H_2O$

c $FeCO_3 + \_\_\_\_ \longrightarrow FeSO_4 + CO_2 + \_\_\_\_$

d $Na_2CO_3 + 2\_\_\_\_ \longrightarrow 2NaNO_3 + \_\_\_\_ + H_2O$

e $\_\_\_\_ + 2HNO_3 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$

5 It's your choice

Copy and complete the following sentences, choosing the correct words.

A metal oxide reacts to neutralise an **acid / a base / a salt.**

The metal oxide is acting as **an acid / a base / a salt.**

The products of the reaction are a salt and **carbon dioxide / hydrogen / water.**

6 Missing materials

Copy and complete the table below.

Reactants		Salt formed	Other product/s formed
magnesium	nitric acid		hydrogen
	hydrochloric acid	copper chloride	carbon dioxide and water
zinc oxide	sulphuric acid	zinc sulphate	
iron		iron chloride	hydrogen

Patterns of reactivity

Before starting this unit, you should already be familiar with these ideas from earlier work.

- Acids react with some metals, metal carbonates and metal oxides. A salt is formed in these reactions, along with other products. Can you write a word equation for the reaction between magnesium carbonate and hydrochloric acid?
- Many metals react with oxygen in the air to form the metal oxide.

You will meet these key ideas as you work through this unit. Have a quick look now, and at the end of the unit read them through slowly.

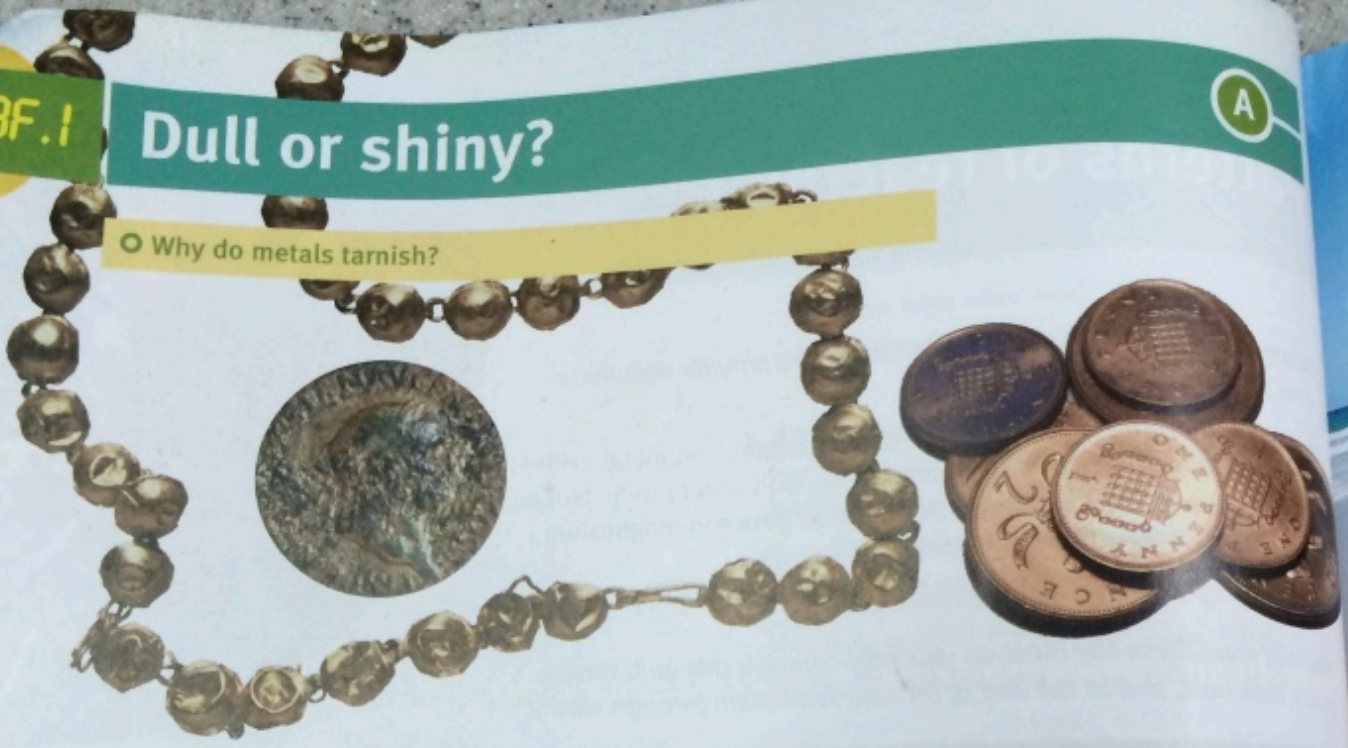
- Some metals react with oxygen very readily. The reaction starts as soon as you put the metal out in the air. You have to heat other metals to make them react, and there are some metals that will not react with oxygen at all. They stay shiny forever.
- Metals can also react with water – some in spectacular fashion, others much more slowly.
- This difference in speed of reaction is called **reactivity**. A metal that reacts readily, such as potassium, is a **reactive** metal. One that doesn't react at all, such as gold, is **unreactive**.
- We can compare how readily different metals react with oxygen. Then we can write a list of the metals in order of reactivity. A list like this is called a **reactivity series**.
- The reactivity series of metals reacting with water and with oxygen is the same as the series of metals reacting with acid.
- We use metals in different ways according to how reactive they are. For example, using caesium to make knives and forks would make an explosive dinner party! We need a metal that won't react with air, water or dilute acids for long-lasting cutlery.
- We can also predict how a particular metal might react by looking at its place in the reactivity series. If magnesium bubbles fast in hydrochloric acid, and we know that zinc is less reactive, we might expect zinc to react but not to bubble quite so fast.
- A metal may react with the solution of a salt of another, less reactive metal. It takes the place of the less reactive metal in the compound. This is called **displacement**.

9F.1

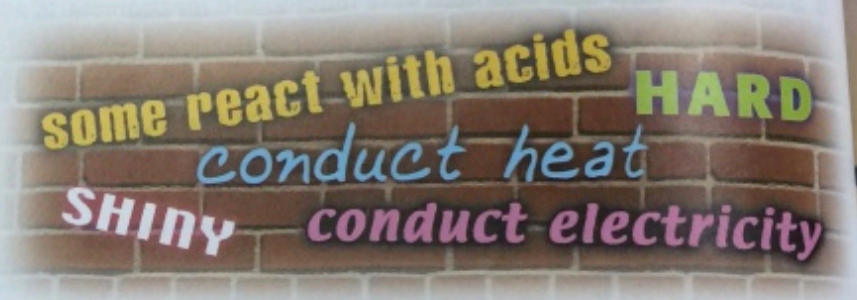
Dull or shiny?

A

- Why do metals tarnish?



This gold necklace is about 2000 years old, but it looks almost new. The copper coin is the same age but it is no longer shiny like the new coins. It has become dull and **tarnished**. The metal has reacted with moisture and oxygen in the air over the years.

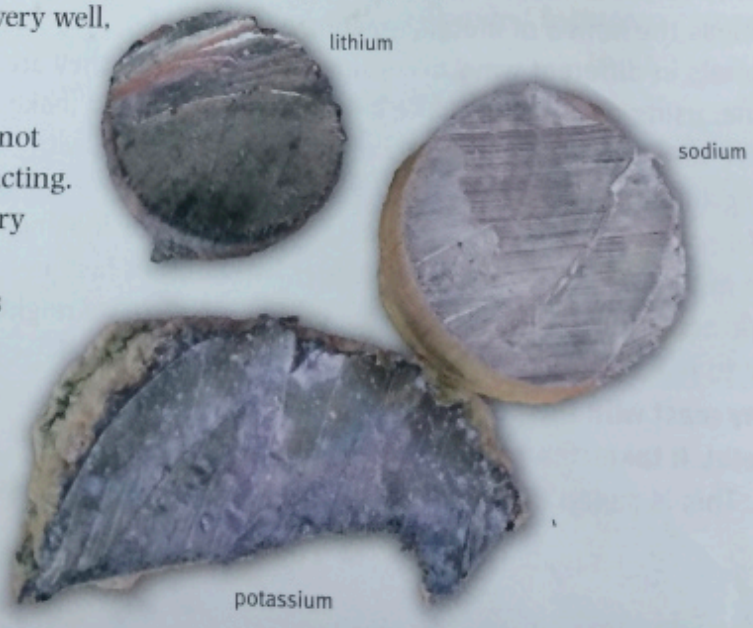


Do you remember the properties of metals?

Meet some soft reactive metals

Lithium, sodium and potassium are a group of elements on the far left of the periodic table. These metals do not behave as you might expect. They conduct heat and electricity very well, but they have some very different properties:

- They are very reactive – you cannot leave them out without them reacting.
- They become dull and tarnish very quickly in air.
- They are not hard or tough – it is easy to cut them with a knife.

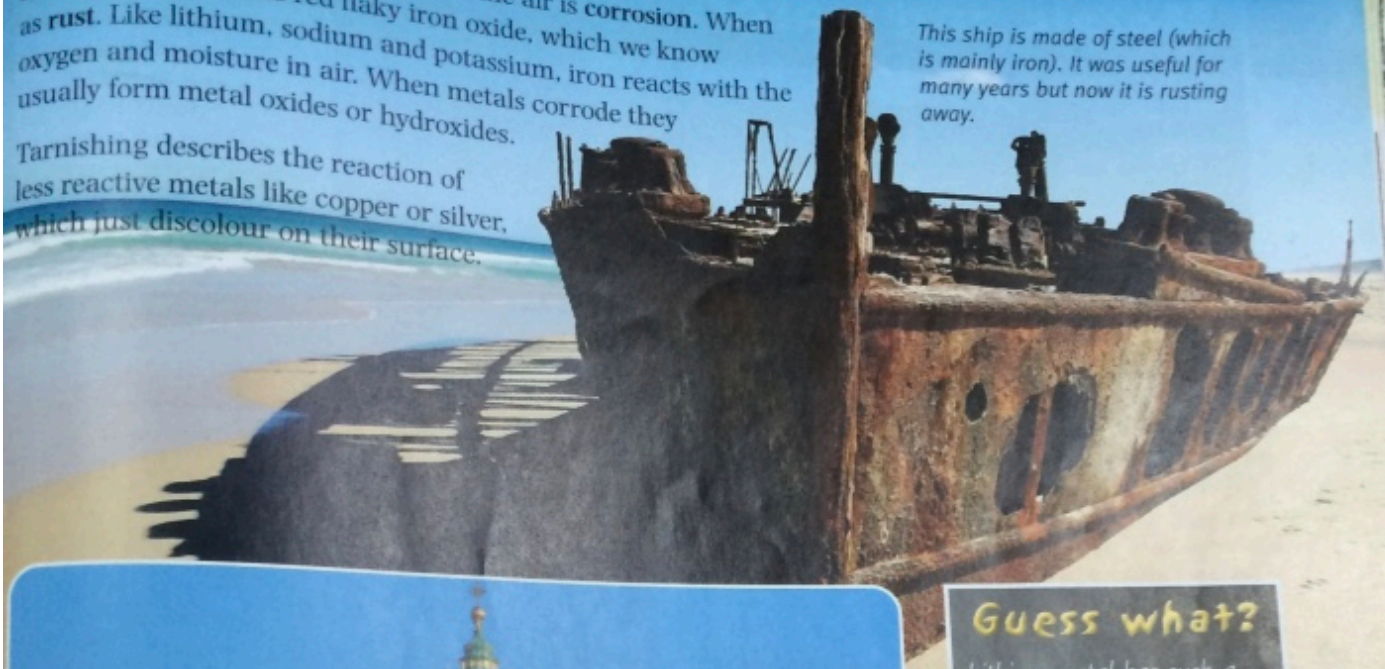


These pieces of lithium, sodium and potassium have just been cut with a sharp knife. They are so reactive that the freshly cut surfaces are soon becoming dull. This is because the metals react with oxygen and moisture in the air.

Corrosion

Another name for metals reacting in the air is **corrosion**. When iron corrodes it forms red flaky iron oxide, which we know as **rust**. Like lithium, sodium and potassium, iron reacts with the oxygen and moisture in air. When metals corrode they usually form metal oxides or hydroxides.

Tarnishing describes the reaction of less reactive metals like copper or silver, which just discolour on their surface.



This ship is made of steel (which is mainly iron). It was useful for many years but now it is rusting away.

Copper tarnishes to this green colour, but it does not corrode away like iron.

Guess what?

Lithium metal has such a low density that it floats on water. But a ship built from lithium would not last long!

Are metals materials that are shiny?

Well glass shines too but it is not a metal. Most metals are shiny but some go dull in air and water.

1 Copy and complete using words from the Language bank:
Metals react with air in different ways. It is the _____ in air along with moisture that cause this _____.

2 What does tarnishing mean?

3 What is formed when iron reacts with air and moisture?

4 Why is lithium unsuitable for ship-building?

5 Find out the answers to these questions.
a How do we remove tarnishing from metals like silver?
b How can we stop metals tarnishing?

Language bank

corrosion
dull
moisture
oxygen
reactive
rust
shiny
tarnished
unreactive
water

9F.2 Metals and water

A

- How do metals react with water?
- Is the order of reactivity of metals with water the same as that with acids?

How do metals react with water?

A gold ring does not react with water, even if the water is very hot. But some metals do react with water. Here is a general equation:

metal + water → metal hydroxide + hydrogen

The metal replaces a hydrogen in the water. The metal hydroxide and hydrogen are formed.

The metal caesium reacts so quickly with water that it explodes, shattering the container. Caesium is an extremely reactive metal.

Looking at potassium, sodium and lithium with water

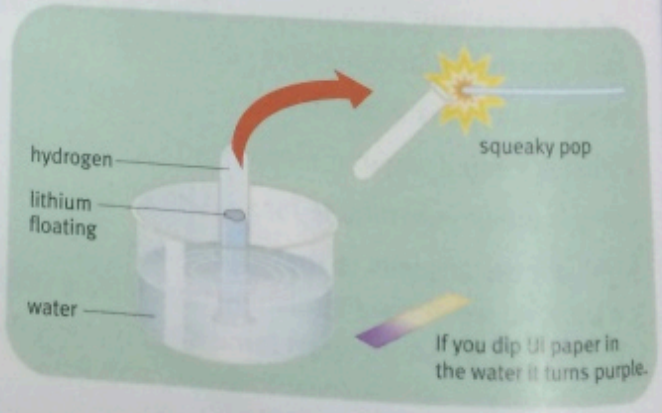
Potassium reacts so violently it bursts into flames, burning the hydrogen that is formed.

Sodium reacts less vigorously without the hydrogen burning, but it gives out so much heat that it melts.

Lithium fizzes gently and skates around on the surface of the water.

Testing the products

You can collect the gas and test for hydrogen using the squeaky pop test. The water in the trough is alkaline. The metal hydroxide makes it alkaline, as you can see in the diagram opposite



Slightly slower

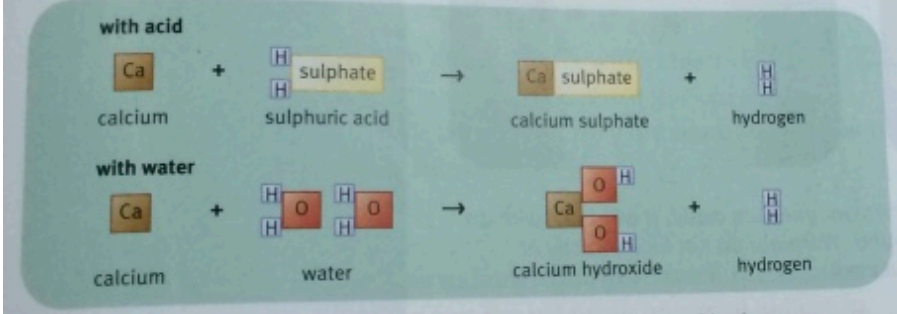
Calcium (left) is not as reactive as potassium, sodium, or lithium. It fizzes gently in water. Magnesium (right) reacts very slowly, showing a few bubbles on its surface after a couple of hours. It's faster using hot water.

Copper and unreactive metals like silver do not react at all with water. This is why we can use them in contact with watery liquids.

Back to the reactivity series

On page 59 we listed metals in order of how quickly they react with acids. We can also make a reactivity series based on how quickly metals react with water, as shown on the right.

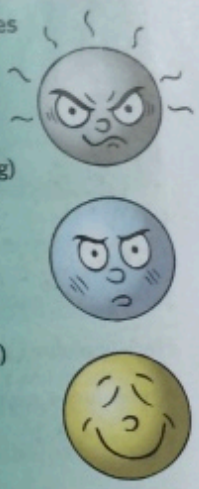
The two lists are the same. This is because when a metal reacts with acid or water, it takes the place of hydrogen.



This simplified diagram shows how calcium takes the place of hydrogen.

Reactivity series

potassium (K)
sodium (Na)
calcium (Ca)
magnesium (Mg)
aluminium (Al)
zinc (Zn)
iron (Fe)
lead (Pb)
(hydrogen (H))
copper (Cu)
silver (Ag)
gold (Au)



1 Copy and complete using words from the Language bank:
Some metals react with _____ to form the metal hydroxide and _____ gas. Other metals do not. We can write a _____ by comparing how quickly metals react with water.

2 Give two pieces of evidence to show that a chemical reaction takes place between sodium and water.

3 What is a reactivity series?

4 A label on a bottle of sodium recommends that the metal is kept under oil. Explain why this is.

5 Write a word or symbol equation for the reaction of calcium with water. (Hint: The formula for calcium hydroxide is $Ca(OH)_2$.)

Language bank

alkaline
hydrogen
metal
metal hydroxide
reactive
reactivity series
unreactive
water

9F 3 Metals and oxygen

- Can we make predictions about the reactions of metals with oxygen?

You have probably seen magnesium burning to make magnesium oxide. The metal reacts with oxygen as it burns. You can burn it in air, because there is oxygen in air, or you can fill a gas jar with oxygen from a cylinder and burn it in pure oxygen.

Magnesium burns well in air (left) to form magnesium oxide. It will burn with an even brighter flame in pure oxygen (right). Warning: do not look directly at burning magnesium as it can hurt your eyes.

Here is a word equation for the reaction:

magnesium + oxygen → magnesium oxide

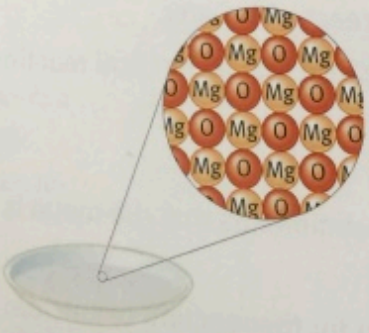
A general equation for the reaction of a metal with oxygen is:

metal + oxygen → metal oxide

You can tell a reaction is happening because:

- a new material is formed that is different from the metal
- heat and light energy are given out – energy is transferred in chemical reactions.

If you weighed the metal before and after the reaction, you would find that its mass increased as it reacted with oxygen.



Magnesium oxide contains magnesium and oxygen atoms.

When something reacts with oxygen an oxide is formed. The reaction is called **oxidation**.

Iron reacts with oxygen to form iron oxide. This is the reaction that happens in sparklers.

Remember the reactivity series

Page 71 lists the metals in order in the reactivity series. We can use this to predict how each metal will react with oxygen. We would expect potassium, sodium and lithium to react more violently than magnesium, and copper and silver to react slowly.

Even a tiny amount of sodium burns violently in oxygen. Sodium oxide is formed.

Copper burns with a green flame to form copper oxide. It reacts much more slowly than sodium.

Guess what?

You might expect aluminium to react with the oxygen in the air more quickly than iron, because it is higher in the reactivity series. But unlike flaky iron oxide, aluminium oxide forms a coating on the metal. This protects it from further reactions. This makes aluminium very useful because it does not corrode as quickly as it would without this oxide layer.

More about reactivity

You can think of reactivity as a drive to react with other things. Generally chemicals 'want' to be as stable as possible. Gold is already stable as it is. For others such as potassium, they are more stable if they react and combine with other substances.

More about oxides

If you put a metal oxide such as sodium oxide into water, the solution is alkaline. You can see this if you test the pH using universal indicator. On the other hand, solutions of non-metal oxides are usually acidic.

Burning sodium produces sodium oxide. If you touch this with damp UI paper, you can see that it forms an alkaline solution.

1 Copy and complete using words from the Language bank:

Metals react with oxygen to form a metal _____ . Some metals burn brightly while others react more slowly, depending on their _____ . A reaction with oxygen to form an oxide is called an _____ reaction.

2 Write each beginning with its correct ending.

Metal oxides tend to be ...	... acidic.
Non-metal oxides tend to be ...	... basic.

3 The order of reactivity of metals with acids and with oxygen is the same. Give examples that show this.

4 Write word equations for the oxidation reactions shown on these two pages.

Language bank

acidic
alkaline
oxidation
oxide
oxygen
pH
reactivity

9F.4 Metals pushing in

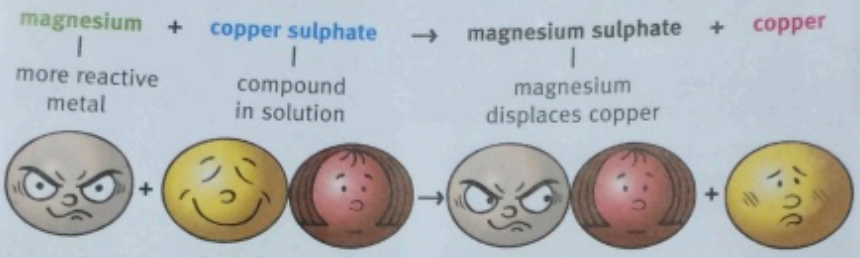
M

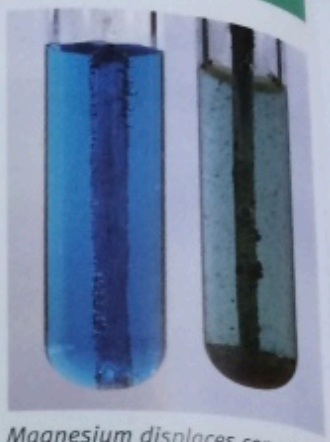
Can metals displace each other?

It's a knock-out

You have seen how we list metals in order of reactivity depending on how quickly they react with acid, water or oxygen. There is another way of comparing the reactivity of different metals.

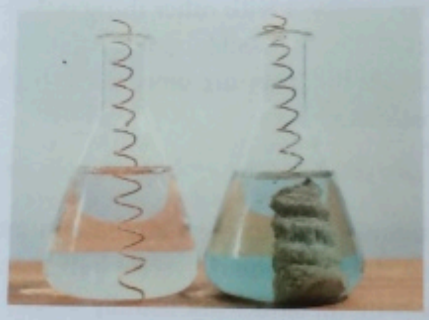
If you have a compound of a metal, then a more reactive metal will knock out or **displace** this metal from its compound. You can see this if you have a solution of a metal salt and add a more reactive metal to it. The picture shows an example, adding magnesium to copper sulphate.





Magnesium displaces copper from copper sulphate. Magnesium sulphate solution is formed, which is colourless. Copper is deposited on the magnesium and falls to the bottom of the tube.

Copper is less reactive than magnesium, zinc and iron. But copper will displace silver from silver nitrate solution. The picture shows silver forming on the copper wire. The solution is turning blue as the copper salt is formed.



Copper is more reactive than silver, so copper displaces silver from silver nitrate solution.

Metal added \ Salt solution	magnesium sulphate	zinc sulphate	iron sulphate	copper sulphate
magnesium		zinc deposited ✓	iron deposited, green solution loses its colour ✓	copper deposited, blue solution loses its colour ✓
zinc	no reaction ✗		iron deposited, green solution loses its colour ✓	copper deposited, blue solution loses its colour ✓
iron	no reaction ✗	no reaction ✗		copper deposited, blue solution loses its colour ✓
copper	no reaction ✗	no reaction ✗	no reaction ✗	

Some displacement reactions

The table shows what happens if you add some metals to solutions of other metal sulphates. The more reactive metal displaces the less reactive metal from its compound. If there is no reaction, this shows that the metal you are adding is less reactive than the metal in the sulphate.

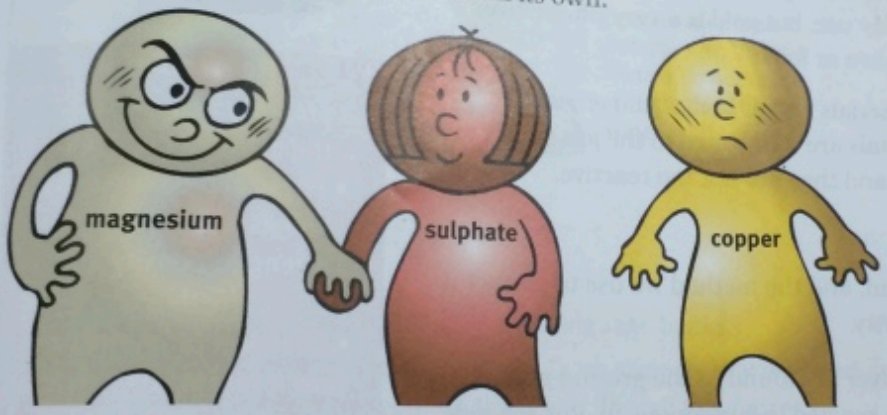
A model for displacement

We can explain what is going on in displacement reactions by comparing them with something else. We call this sort of explanation a **model** or an **analogy**.

This is what is happening.

more reactive metal + less reactive metal sulphate → more reactive metal sulphate + less reactive metal

Think of reactive metals as being able to hold onto things they are joined to better than less reactive metals can. Magnesium holds onto the sulphate better than copper, so it displaces the copper in the compound. This leaves the copper all on its own.



The pull of the reactive magnesium is greater than the pull of the copper so magnesium wins and displaces copper.

Guess what?

The **thermit reaction** uses aluminium and iron oxide, along with some other ingredients to get the reaction going. Aluminium is higher than iron in the reactivity series so it displaces iron from the iron oxide. The reaction produces a lot of heat energy and so molten iron is produced. The thermit reaction is sometimes used to weld railway lines together. The molten iron is poured between sections of track to join them up.

1 Copy and complete using words from the Language bank:

A metal will _____ a less _____ metal from its compound. It is as if the more _____ metal has a greater pull so holds onto the compound better.

2 What is an analogy?

3 Imagine that you have a friend who has missed a lesson on displacement reactions. Explain to your friend what you know so far about displacement reactions.

4 Choose three reactions shown on these two pages and write word or symbol equations for them.

Language bank

analogy
compound
displace
displacement
model
reactive
reactivity
replace
thermit reaction

9F 5

Extracting and using metals

S

- How does the activity series relate to uses and sources of metals?

The best metal for the job

Have you ever thought why knives and forks are made of steel (iron), or silver? Can you imagine what it would be like if they were made of a metal like sodium, which reacts violently with water? Life would certainly be interesting. And why do people have gold teeth rather than magnesium teeth?

Different metals have their own physical and chemical properties which make them good for certain jobs. These properties depend on their reactivity. Sodium is too reactive for everyday use, but gold is a very unreactive metal and does not react with saliva or food.

Aluminium or steel are good materials for car bodies and engine parts because the properties of the metals are well suited to the job. They can be shaped easily, they are strong and they are not too reactive.

Remember

A **property** describes how the material behaves.

- Physical properties are things like hardness, strength, density and ductility.
- Chemical properties are how it reacts, such as its reactivity with oxygen, acids and water.

Extracting metals

How we find a metal in the ground, and the method we use to extract it from its ore, is linked to its reactivity.

Unreactive metals like gold and silver are found in the ground **native** (as the metal element rather than reacted in a compound). But reactive metals quickly combine with materials in the ground to form compounds which we call **ores**.

If you were very lucky you might find pure gold in the ground or on a river bed.

This ore contains iron oxide. We need a reaction to extract the iron.

- We don't need a chemical reaction to extract gold or silver.
- To extract more reactive metals like zinc or iron we heat the ore with carbon. The carbon displaces the metal.
- For very reactive metals that are more reactive than carbon, we need to pass electricity through the ore to extract the metal. The process is called **electrolysis**. Electrical energy is used to split the melted or dissolved ore and separate out the metal. It is a very expensive process.

Metal	Extracted by	
potassium	electrolysis	more reactive than carbon so carbon can't be used to extract these metals
sodium	electrolysis	
calcium	electrolysis	
magnesium	electrolysis	
aluminium	electrolysis	
(carbon)		
zinc	smelting with carbon	less reactive than carbon so carbon will displace these metals from their ores
iron	smelting with carbon	
lead	smelting with carbon	
(hydrogen)		
copper	sometimes found native, sometimes as an ore which can be extracted with carbon	less reactive than hydrogen so these metals do not react with dilute acids or water
silver	found native	
gold	found native	

Guess what?

Aluminium is a very useful metal but it is difficult to extract. People discovered it much later than iron and copper. This is why we see iron, copper, silver and gold finds but no aluminium objects in ancient archaeological sites.

1 Copy and complete using words from the Language bank:

Very reactive metals are held in their _____ so strongly that we need to use electrical energy to separate them out. We call this process _____ . Less reactive metals can be extracted by heating with carbon which _____ the metal from its ore. This process is called _____ . Very unreactive metals are found _____ in the ground and rivers.

2 Aluminium is quite a reactive metal.

a Is it easy or hard to extract from its ore?

b Is it more or less reactive than iron?

c Was it first used before or after iron?

3 Tin comes between iron and lead in the reactivity series. Predict what method is used to extract tin from its ore.

4 Find out more about the connection between the reactivity of a metal, when it was first used and how it is extracted from its ore.

5 Find out what bronze is. What is it used for? When and what was the Bronze Age? Was it before or after the Iron Age?

Language bank

chemical property
compounds
displaces
electrolysis
extract
extraction
native
ores
physical property
property
reactivity series
smelting

Checkpoint

1 Metals reacting

Midge reacted five metals with water. She listed them in order, fastest reaction first:

potassion
sodion
calcion

Her teacher wouldn't let her try caesium with water as she said it was too dangerous.

Midge also reacted five metals with dilute hydrochloric acid. Here is her list:

calcion
magnesion
zinc

Her friend told her that he'd tried copper with dilute hydrocloric acid and nothing happened. She knows that copper tarnishes in air, while gold stays shiny for years and years.

Copy and complete the following sentences, choosing the correct words.

a A list like the ones Midge made is called an **action list / a reactivity series / a reactivity cycle.**

b If Midge reacted the metals with oxygen, she would expect zinc to react **more quickly than / about the same as / slower than** sodium.

c If Midge combined her lists into one, she should add gold at the **top / bottom** of the list while caesium should be at the **top / bottom.**

2 Writing equations

Write word and symbol equations for the following metals reacting with oxygen.

a magnesium

b copper

c calcium

d iron

3 In order

Predict which reactions in question 2 will be fastest and slowest. List the four metals in order, with the one that reacts fastest with oxygen first. (You can use the information in question 1 to help you.)

4 About metals pushing in

Copy and complete these sentences, unscrambling the words.

A more reactive metal will replace a less reactive metal from its **poodmunc**. This is called a **nicetemsplad** reaction. If you add magnesium to copper sulphate solution, the **gemumians** displaces the copper. Magnesium **peshutla** and copper metal are formed.

5 Will it displace?

Predict whether a displacement reaction will happen if you mix these together. If yes, write a word equation. If you can, try to write a symbol equation for the reaction too.

a zinc and copper sulphate solution

b iron and sodium chloride solution

c calcium and zinc nitrate solution

d gold and copper nitrate solution

e magnesium and iron sulphate solution