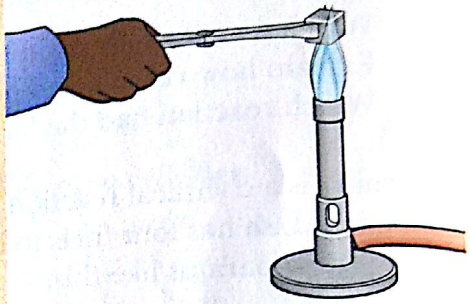
6.1 Metals and their reactions with oxygen

In Stages 7 and 8, you learnt about some of the properties of metals. Now you are going to investigate how different metals react with oxygen.

Activity 6.1
Heating metals in air

SE

In this activity, you will heat several different metals in air. Air contains oxygen, and some of the metals will react with this oxygen.



Read through the instructions and decide on the safety precautions you will need to take. Discuss these with your teacher before you carry out the investigation.

1. Take a small piece of one of the metals provided for you.
2. Place it in the tongs and heat it in a Bunsen flame.
3. Record your observations in a table and explain what has happened.
4. Repeat steps 1 to 3 for each of the other metals your teacher has provided.

Questions

A1 Which was the most reactive of the metals you were given? What evidence do you have for this?

A2 What safety precautions did you take whilst carrying out this investigation?

A3 Are the reactions of Group 1 metals with oxygen more or less vigorous than the ones you tested? What evidence do you have for this?

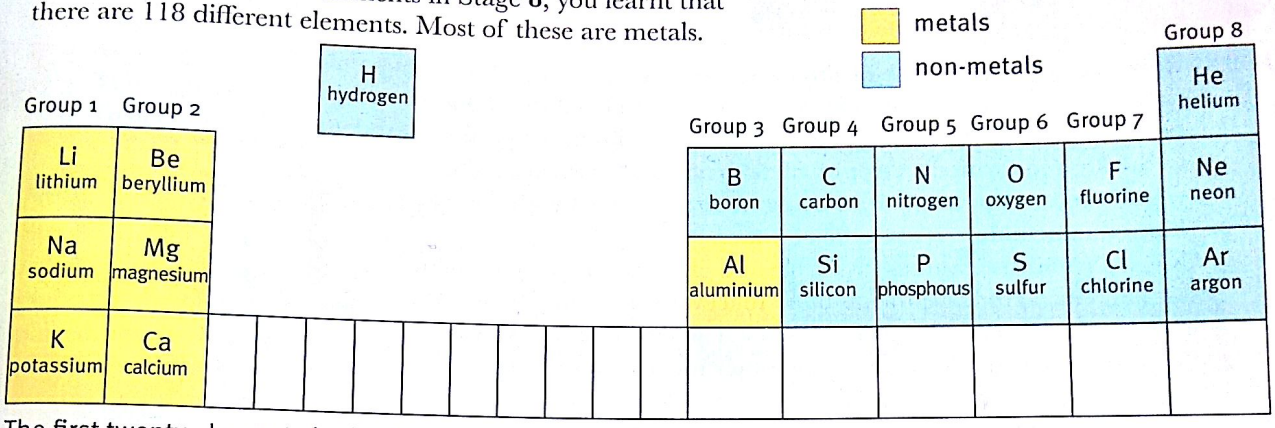
Looking at the reactions of metals with oxygen

Many metals react with oxygen if they get hot enough. You have seen magnesium react with oxygen when you heat it. You have also seen the effect of iron reacting with oxygen when it rusts.

When you look carefully at the reactions of metals with oxygen, it is possible to identify which metals are more reactive. We can say that magnesium is more reactive than iron because we can see that iron reacts much more slowly than magnesium.

Metals and the Periodic Table

When you looked at the elements in Stage 8, you learnt that there are 118 different elements. Most of these are metals.



The first twenty elements in the Periodic Table.

Each of the elements has a different atomic structure with a different number of electrons, protons and neutrons. The atoms of the different elements are different sizes.

Metals have some properties in common and some properties that are slightly different. For example, iron is hard and strong but sodium is much softer and can be easily cut with a knife.

Reactions of Group 1 metals with oxygen

The metals in Group 1 of the Periodic Table are softer than other metals. They are also more reactive than other metals. They must be stored under oil because they react vigorously with the moisture in the air and can explode.

When pieces of lithium, sodium or potassium are taken out from their containers, they appear dull (not shiny). When the pieces are cut, the surface is shiny. The shiny surface soon becomes dull because the metal reacts with the oxygen in the air. The surface becomes covered with a new substance – the oxide of the metal. These metals are so reactive that they react with oxygen even when they are not heated.

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

metal + oxygen → metal oxide

Questions

A+I

1 Name **two** metals that have atoms larger than those of sodium.
2 Which property of sodium is not typical of a metal?
3 Suggest why it might be difficult and dangerous to test sodium for electrical conductivity.
4 Write the word equation for the reaction of sodium with oxygen.

Summary

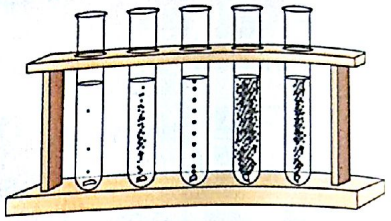
- When a metal reacts with oxygen a metal oxide is formed.
- Metals have different levels of reactivity.

6.2 Reactions of metals in water

Activity 6.2
Reactions of metals in water

SE

1 Take a small piece of one of the metals provided for you. Use sandpaper to clean the surface of the metal. You need to do this because some of the metals may have reacted with the oxygen in the air and formed a layer of metal oxide on the surface. This would prevent the metal from being in direct contact with the water.
2 Place the metal into a test tube of water.
3 Record your observations in a table and explain what has happened. You may need to leave the metal to react for some time. If nothing happens, you could try testing the metal again using hot water.
4 Repeat steps 1 to 3 for each of the other metals your teacher has provided.

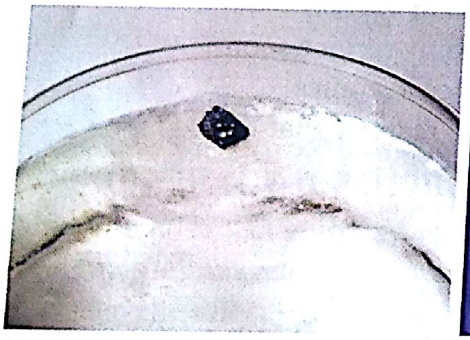


Questions

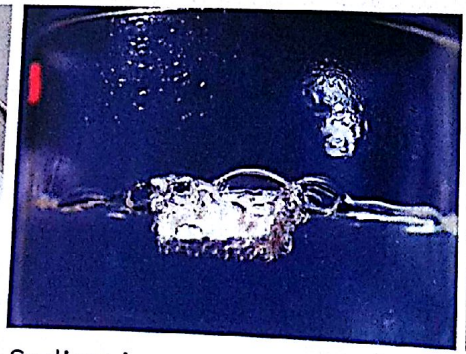
A1 Which was the most reactive of the metals you were given? What evidence do you have for this?
A2 Use the results of your experiment to arrange the metals in order of their reactivity, starting with the most reactive.
A3 Suggest why some metals will react with hot water but not with cold water.

Reactions of Group 1 metals with water

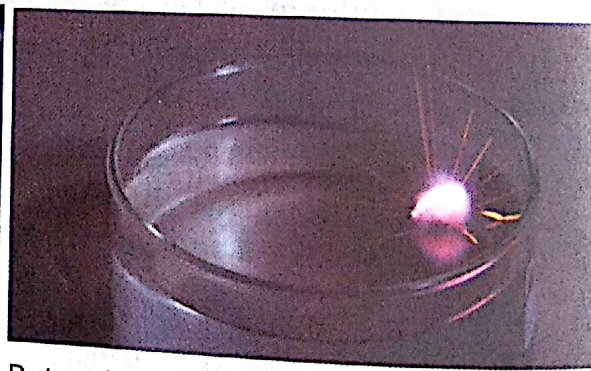
In Stage 8 you learnt about the reaction of some metals with water. You saw the reactions of lithium, sodium and potassium when pieces of each metal were placed on water.



Lithium reacts with water to produce lithium hydroxide and hydrogen.



Sodium is more reactive than lithium with water.



Potassium is even more reactive than sodium. So much heat is generated that the hydrogen gas produced catches fire

Look at the position of these three metals in Group 1 in the Periodic Table on page 81. Potassium is the most reactive and is lower down the group. Lithium is the least reactive and is at the top of the group.

In all three of these reactions the metal reacted with water to produce hydrogen and the metal hydroxide.

$$\text{metal} + \text{water} \rightarrow \text{metal hydroxide} + \text{hydrogen}$$

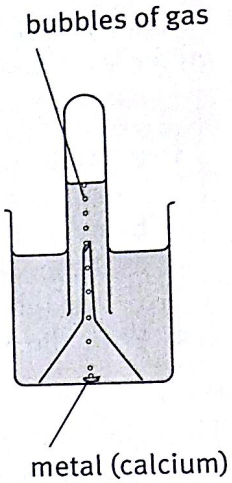
Questions

SE

1 Which of these three metals – sodium, lithium and potassium – reacts the most vigorously?
2 Write the word equation for the reaction of sodium with water.
3 What safety precautions must be taken when these reactions take place?
4 Explain why these metals must be stored under oil.

Reactions of other metals with water

Some other metals react less vigorously with water – for example, magnesium and calcium. In the experiment shown in the diagram, a piece of calcium has been placed in the bottom of a beaker and covered with water. A filter funnel has been placed upside down over the metal. The gas given off is collected in a test tube by the displacement of water.



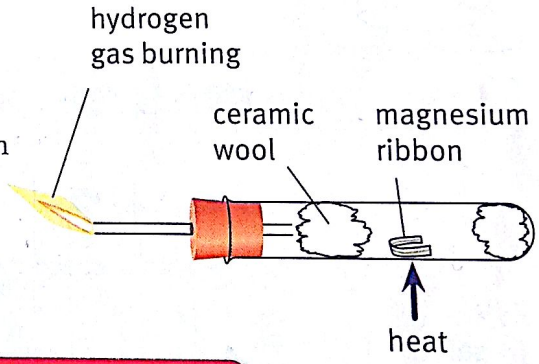
Questions

5 What is the gas that is given off? How would you test for it?
6 How could you tell if calcium or magnesium is the more reactive?
7 What factors should you take into account to make this a fair test?
8 Write the word equation for the reaction between calcium and water.

Some of the metals that do not react with water may react with steam. Even magnesium will react more rapidly with steam than with water.

In the reaction shown on the right, magnesium is heated. From time to time the ceramic wool is also heated. The ceramic wool has been soaked in water, which produces steam. In this reaction the magnesium reacts with water in the form of a gas. Magnesium oxide and hydrogen are formed. The hydrogen gas that is given off can be burnt. The word equation for this reaction is:

magnesium + steam → magnesium oxide + hydrogen



Questions

A+I

9 Explain, using particle theory, why the reaction between steam and magnesium is more vigorous than that between liquid water and magnesium.

Summary

- Group 1 metals react vigorously with water.
- The metals nearest the bottom of Group 1 in the Periodic Table react more vigorously than those at the top.
- Some metals will react with hot water or steam, but not with cold water.

6.3 Reactions of metals with dilute acid

You will probably remember seeing the reaction of magnesium with hydrochloric acid. This is the word equation for this reaction:

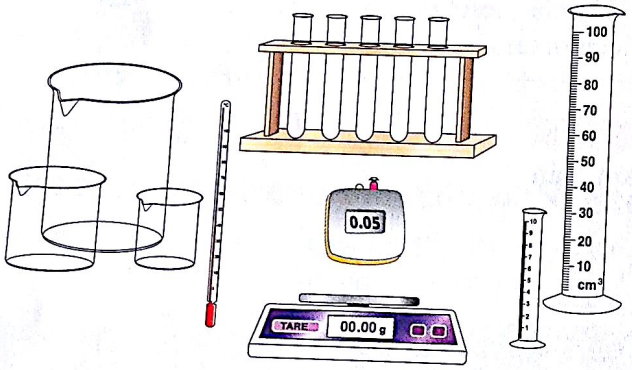
magnesium + hydrochloric acid → magnesium chloride + hydrogen

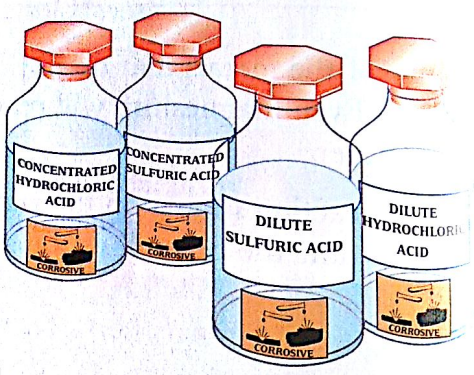
Magnesium chloride is an example of a **salt**. When a metal reacts with an acid, the products are a salt and hydrogen.

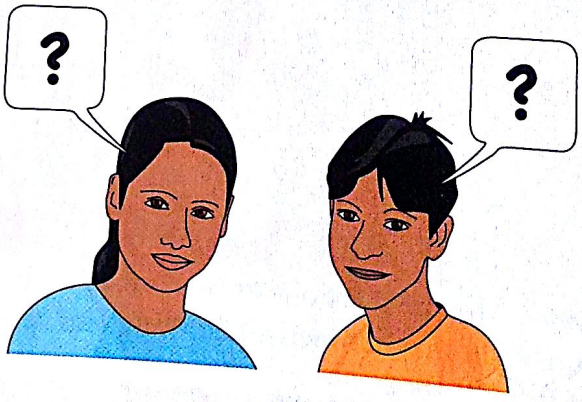
Questions

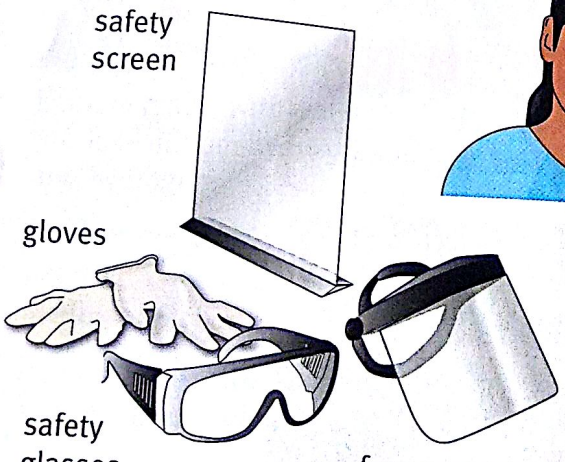
1 a Write the word equation for the reaction between magnesium and sulfuric acid.
  b What is the salt that is produced in this reaction?
  c Describe what you would observe if this reaction took place in a test tube.
2 Write the word equation for the reaction between zinc and nitric acid.

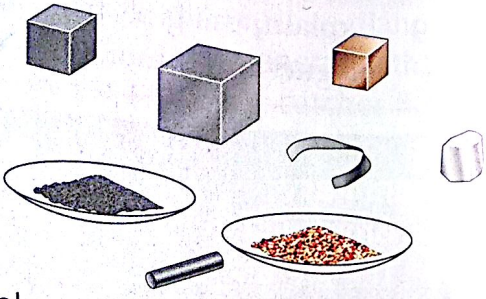
Priya and Rohit have been asked to investigate the reactivity of metals with acids. The equipment and reagents that are available in the laboratory are shown below. Their first task is to plan their investigation. They need to choose which items they will use. They need to decide how they will carry out the investigation.











Metals, such as magnesium, copper, iron, aluminium, zinc, lead, in the form of blocks, filings or powder.

Activity 6.3A

Plannning an investigation into the reactivity of metals in acid

SE

Use the information and ideas on the previous page to plan the investigation for Priya and Rohit. Choose which of the items in the diagrams they need to use. Some of the items shown are not appropriate to use.

Discuss in your group how you will answer these questions.

- What will they change?
- What will they keep the same?
- How will they measure the reactivity and decide which is the most or least reactive metal?
- How will they keep safe?
- What equipment will they use?

Remember to include a results table and an idea of what they should be looking for in order to identify which are the most reactive.

Write your plan and show your teacher.

Questions

A1 Which metals should **not** be used by the students in this investigation? Give reasons for your answer.

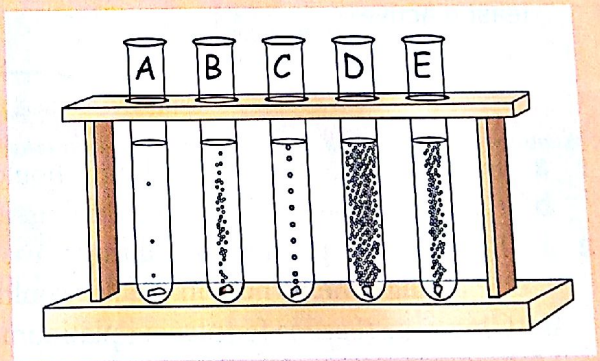
A2 Explain which measuring cylinder they should choose to measure out enough acid to use in this investigation.

Activity 6.3B

Investigating the reactivity of metals in dilute acid

SE

Your teacher will provide you with the items you need to carry out this investigation. Your task is to find the order of reactivity of the metals you are given. Remember to work in a methodical way and keep an accurate record of your results.



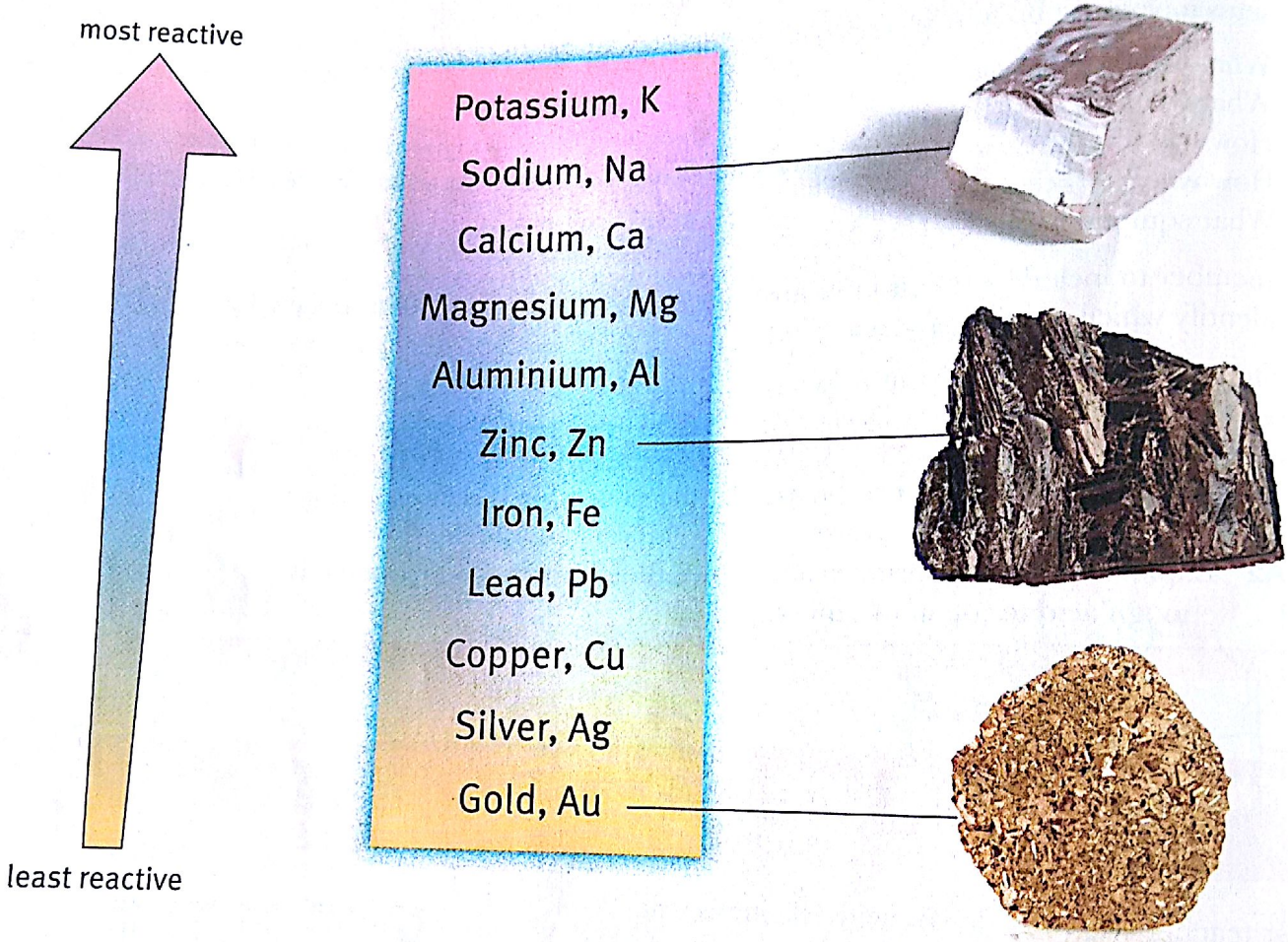
Summary

- When a metal reacts with dilute acid, the products are a salt and hydrogen.
- Different metals have different levels of reactivity in dilute acid.

6.4 The reactivity series

You have seen that some metals are more reactive than others by looking at the reaction of the metals with oxygen, water (or steam) and dilute acid. Using the results of all of these investigations, we can place the metals in order of their **reactivity**.

This list is called the **reactivity series**. It has the most reactive metals at the top and the least reactive at the bottom.



Questions

A+I

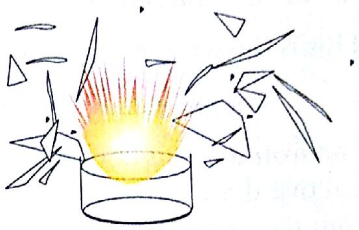
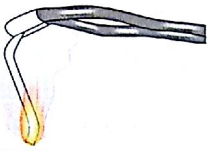
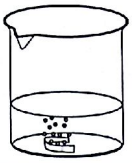
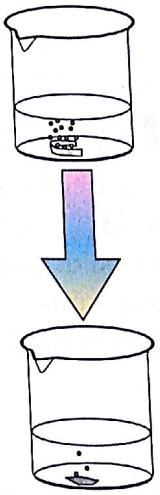
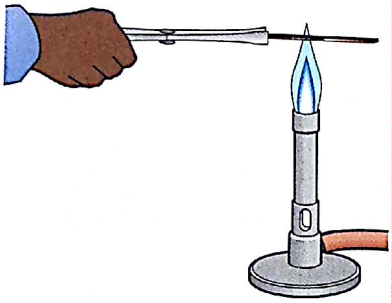
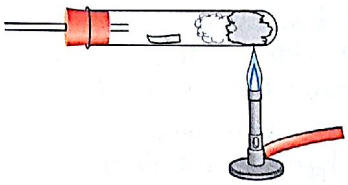
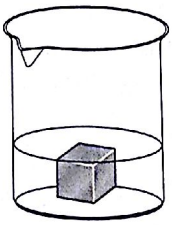
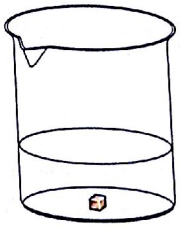
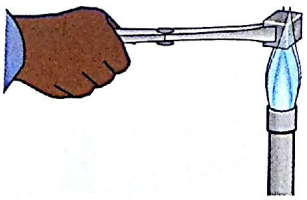
1 **a** Suggest where the metal lithium should be placed in this list.
b Give your reasons for placing lithium in this position.

A+I

2 **a** Platinum is a precious metal that is used for jewellery. Platinum stays shiny for a long time. Where in the list would you place the metal platinum?
b Give your reasons for placing platinum in this position.

3 Make up a mnemonic to help you to remember the sequence of the metals in the reactivity series. (A mnemonic is a sentence in which the first letter of each word is the same as the first letter of the things you want to remember.) You could either use the first letters of the names of the metals, or their symbols.

This table shows a summary of the reactions of the metals in the reactivity series.

<table>
<tr><th>Metal</th><th>Reaction with oxygen</th><th>Reaction with water</th><th>Reaction with dilute acid</th></tr>
<tr><td>potassium</td><td rowspan="2">burns brightly when heated to form an oxide
  </td><td rowspan="2">very vigorous reaction in cold water. The hydroxide is formed
  </td><td rowspan="2">violent reaction and very dangerous
  </td></tr>
<tr><td>sodium</td></tr>
<tr><td>calcium</td><td rowspan="2">burns brightly in air when heated to form an oxide
  </td><td rowspan="2">slow reaction in cold water to form the hydroxide
  </td><td rowspan="3">reaction, which becomes less vigorous as you go down the list
  </td></tr>
<tr><td>magnesium</td></tr>
<tr><td>aluminium</td><td rowspan="3">slow reaction when heated to form an oxide
  </td><td rowspan="2">reacts with steam but not water to form an oxide
  </td></tr>
<tr><td>zinc</td></tr>
<tr><td>iron</td><td>no reaction with steam or water
  </td><td rowspan="2">no reaction
  </td></tr>
<tr><td>lead</td><td rowspan="2"></td></tr>
<tr><td>copper</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>silver</td><td rowspan="2">no reaction
  </td></tr>
<tr><td>gold</td><td></td><td></td></tr>
</table>

Summary

- Metals have different levels of reactivity.
- The reactivity series is a list of metals with the most reactive at the top.

6.5 Displacement reactions

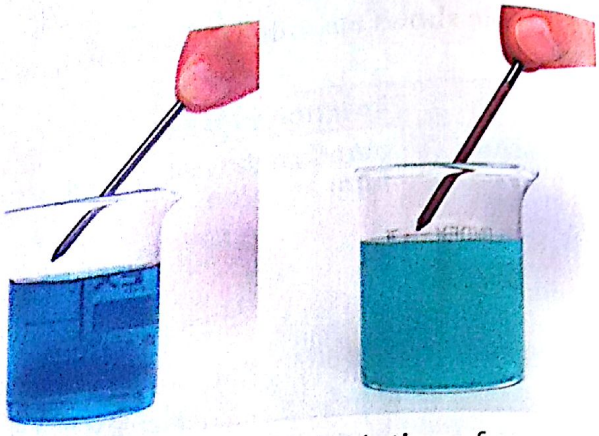
If you place a clean iron nail into a beaker of copper sulfate there is an interesting reaction.

The blue copper sulfate solution changes to a slightly paler colour. The most remarkable thing that happens is that the nail looks a different colour. It has become a copper colour. What has happened in this reaction?

This is the word equation for this reaction.

copper sulfate + iron → iron sulfate + copper

The iron nail has become coated with copper. Iron is more reactive than copper and it has 'pushed out' the copper from the copper sulfate and has reacted to form iron sulfate. This 'pushing out' is called displacement, so this type of reaction is named a **displacement reaction**. A more reactive metal can replace a less reactive one in a salt.



An iron nail is placed in a solution of copper sulfate. When the nail is removed it is covered in copper.

If a copper nail was placed in a solution of iron sulfate there would be no reaction because copper is less reactive than iron. Copper cannot displace the iron in the iron sulfate.

Questions

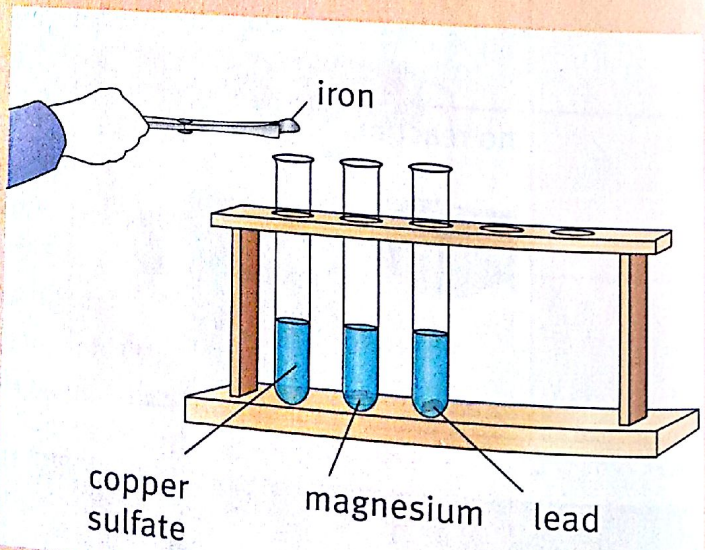
Use the reactivity series on page **86** to help you answer the following questions.

A+I
1 Which is the more reactive metal – zinc or lead?
2 Can zinc displace the lead in lead nitrate?
A+I
3 Which is more reactive – silver or aluminium?
4 Can silver displace the aluminium in aluminium sulfate?

Activity 6.5A
Displacing metals

SE
In this activity you will use four different metals and four different solutions of salts. The solutions are copper sulfate, magnesium sulfate, iron sulfate and lead nitrate. The metals are iron, lead, copper and magnesium.

1 Read through these instructions and prepare a results table. (You will need to think about this quite carefully – there are a lot of different results to record.)
2 Pour copper sulfate solution into three test tubes so that each is about a third full.
3 Add a small piece of iron into one test tube, a small piece of magnesium to the second and a small piece of lead to the third test tube.



continued ...

... continued

4 Leave the test tubes for a few minutes.
5 Observe carefully and record your observations.
6 Repeat steps 2 to 5 using magnesium sulfate solution and the three metals copper, iron and lead.
7 Repeat steps 2 to 5 using iron sulfate solution and the metals copper, magnesium and lead.
8 Repeat steps 2 to 5 using lead nitrate solution and the metals copper, magnesium and iron.

Safety: Lead is toxic. Do not touch the lead metal with your fingers. Use forceps. If you do touch the lead, wash your hands carefully.

Questions

A1 How did you know that one metal had displaced another from its salt?
A2 Which metal was the most reactive?
A3 Which metal was the least reactive?

Activity 6.5B
Mystery metal

SE

In this activity you have to identify a mystery metal. It is one of the metals from the reactivity series. You are going to investigate which metal it could be.

Remember your safety!

You do not know what the metal is, so treat it with care and pick it up with forceps.

Add a piece of your mystery metal to each of the solutions provided, and decide if a reaction has taken place or not.

Record your observations.

After each test you will be able to cross some metals off your list.

Questions

A4 What do you think the mystery metal is?
A5 Give your reasons for your answer.

Summary

- More reactive metals can displace less reactive ones from solutions of salts.
- Metals can be identified by observing their reactions.

6.6 Using displacement reactions

Aluminium is more reactive than iron. Aluminium will displace iron from solid iron oxide if it is heated.

aluminium + iron oxide → aluminium oxide + iron

This reaction releases a lot of energy. It is an exothermic reaction. The temperature gets so high that the iron that is produced is molten (in a liquid state). The melting point of iron is 1535 °C. This reaction is very useful and is used by railway companies to weld rails together.

In the photograph you can see the reaction being used to weld railway rails together. Often, rails need to be welded where the railway lines are. The iron oxide and aluminium powder react in a container placed on the rails. The molten iron produced in the reaction is shaped and used to join the rails together. This reaction is called the **thermite reaction**.

Welding railway rails usi an exothermic reaction.

In order for the reaction to take place, the iron oxide and aluminium mixture has to be ignited. This is done using another exothermic reaction – this time between magnesium powder and barium nitrate. This provides the energy to start the displacement reaction between the aluminium and iron oxide.

Questions

1 Can iron displace aluminium from aluminium oxide? Explain your answer.
2 Why is the thermite reaction useful for welding rails?

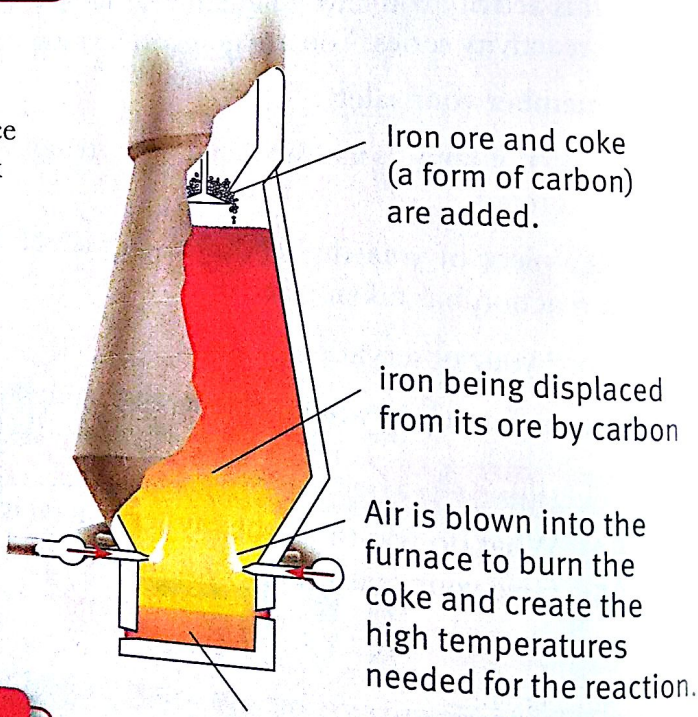
Displacement using carbon

Carbon is not a metal, but it can be used to displace some metals from their compounds. Carbon will displace zinc, iron, tin and lead from their **ores**. An ore is a rock that contains a metal compound.

People discovered that carbon could displace iron around 3500 years ago. They discovered that iron ore heated with charcoal (a form of carbon) at very high temperatures produced molten iron. Today this displacement reaction is still carried out, but on a large scale, in a **blast furnace**.

The iron ore is mainly iron oxide. This reacts with carbon to form iron and carbon dioxide.

iron oxide + carbon → iron + carbon dioxide



A blast furnace.

Questions

3 The early blast furnaces were in areas where there were supplies of iron ore and a lot of coal mining. Why do you think this was?

Activity 6.6
Extracting metals using carbon

SE

In this activity you will use carbon to try to displace a metal from its oxide. Remember that carbon will only displace a metal that is less reactive than itself. Wear safety glasses for both these experiments.

Experiment 1

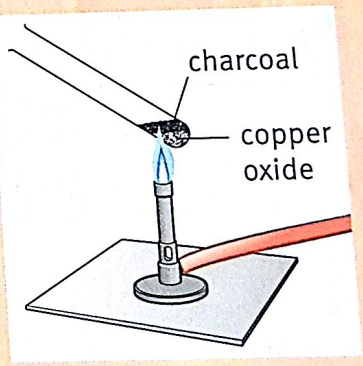
1 Place a spatula of lead oxide in a container, such as a small beaker. Avoid touching the lead oxide, but if you do, wash your hands as soon as possible.
2 Add a spatula of charcoal powder and mix the two powders together thoroughly.
3 Place the mixture in a test tube and heat strongly in a Bunsen flame for five minutes.
4 Allow the tube to cool. Tip the cooled contents of the tube onto a heatproof mat.
5 Record your observations.

Questions

A1 Has there been a reaction between the lead oxide and the carbon? Give reasons for your answer.
A2 If there has been a reaction, write a word equation for it.
A3 What evidence does this experiment give you about the reactivity of carbon?

Experiment 2

1 Place a spatula of copper oxide in a test tube.
2 Add a spatula of charcoal powder on top of the copper oxide. Do not mix the powders together.
3 Heat the two layers strongly in a Bunsen flame for five minutes.
4 Allow the tube to cool and then look carefully where the layers meet.
5 Record your observations.



Questions

A4 Has there been a reaction between the copper oxide and the carbon? Give reasons for your answer.
A5 If there has been a reaction, write a word equation for it.
A6 What evidence does this experiment give you about the reactivity of carbon?
A7 Where would you place carbon in the reactivity series?

Summary

- The thermite reaction is a displacement reaction which can be used to weld railway lines together.
- Displacement reactions are used to extract some metals from their ores.

Unit 6 End of unit questions

6.1 Hana placed five metals in water. She also placed four of the metals in dilute acid. Her observations are recorded in the table.

Metal	Reaction with water	Reaction with dilute acid
aluminium	No reaction.	Bubbles of gas are given off.
sodium	There is a very vigorous reaction. Sodium gives off bubbles of gas and the gas ignites.	
magnesium	Bubbles of gas are given off.	Bubbles of gas are given off very rapidly.
gold	No reaction.	No reaction.
tin	No reaction.	Bubbles of gas are given off very slowly.

a Name another metal that has a similar reaction to sodium.

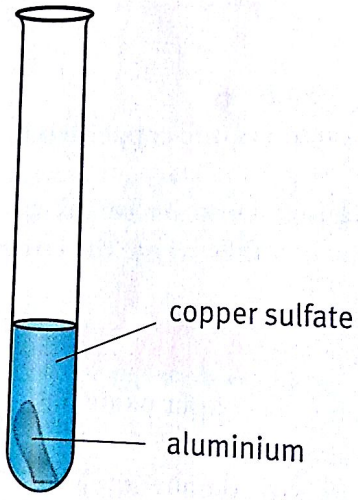
b Suggest why Hana did not place sodium in dilute acid.

c Use Hana's results to place the five metals in order of reactivity, starting with the most reactive.

d Write a word equation for the reaction between sodium and water.

e Write a word equation for the reaction between magnesium and hydrochloric acid.

6.2 Rafa places a piece of aluminium metal into a test tube of copper sulfate.



A reaction takes place.

The word equation for this reaction is:

aluminium + copper sulfate → aluminium sulfate + copper

a How can Rafa tell that a reaction has taken place? [1]

b Why is this reaction called a displacement reaction? [1]

c Rafa then places some zinc in a solution of lead nitrate. A displacement reaction takes place. Write the word equation for this reaction. [2]

d He then places some copper into a solution of sodium chloride. No reaction takes place. Give a reason for this. [1]

6.3 The word equations below represent some displacement reactions.

aluminium	+	copper sulfate	→	aluminium sulfate	+	copper
aluminium	+	lead nitrate	→	aluminium nitrate	+	lead
lead	+	copper sulfate	→	lead sulfate	+	copper
lead	+	silver nitrate	→	lead nitrate	+	silver

a Use the word equations to decide which of the four metals – aluminium, copper, lead and silver – is the most reactive. [1]

b Decide if a reaction will take place when lead is placed in a solution of magnesium sulfate. If you think there will be a reaction, write the word equation for it. [1]

c Decide if a reaction will take place when iron is placed in a solution of lead nitrate. If you think there will be a reaction, write the word equation for it. [1]

6.4 **a** The following equations show four reactions.

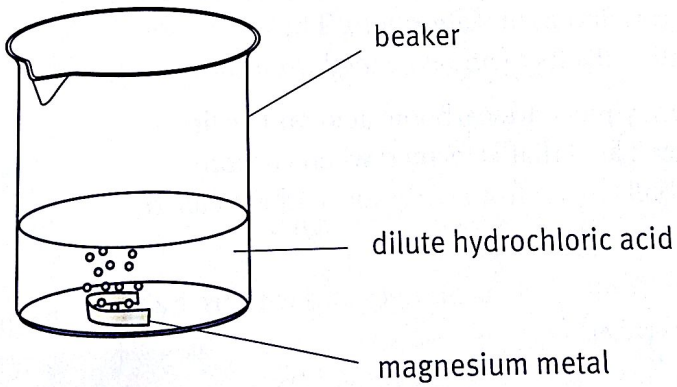
A carbon + oxygen → carbon dioxide
B iron sulfate + zinc → zinc sulfate + iron
C sodium hydroxide + hydrochloric acid → sodium chloride + water
D magnesium + oxygen → magnesium oxide

Give the letter A, B, C or D of the reaction that is:

i a neutralisation reaction [1]
ii a displacement reaction [1]
iii a reaction in which a metal oxide is formed [1]

b What does the reaction in equation B tell you about the reactivity of the two metals involved? [1]

c When magnesium or zinc metal are placed into dilute hydrochloric acid, bubbles of a gas are given off.



What is the name of the gas? [1]