5.3 Finding and extracting metals

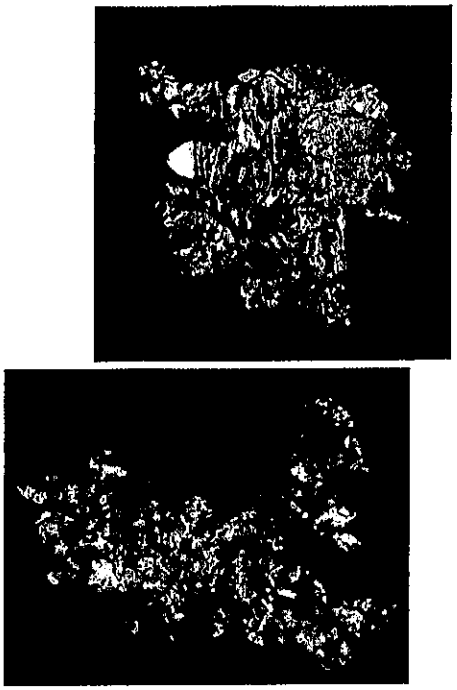


Figure 3.1 *Native gold and silver.*

Where do all the different metals come from? Rocks that contain metals are among our most valuable natural resources. Finding these special rocks and extracting metals has been an important part of chemistry for many years.

Native metals

Small pieces of gold can be found naturally uncombined (as the element) in the ground. For this reason gold has been known and used for thousands of years. Metals that are found free or uncombined in nature are called **native** metals. They are found as elements because they are very unreactive. Platinum and silver are two other metals that can be found in a native state.

Most metals are found in compounds and are not native. This is because they are more reactive and so react with substances around them. For example, most metals react with oxygen and sulphur, forming metal oxides and sulphides.

Rocks from which metals can be extracted are called **ores**. These rocks are not usually pure substances, but are a mixture of compounds. The most common ores usually contain an oxide, sulphide or carbonate of the metal and these compounds have to be broken down to extract the metal.

In 1578 a British ship, on an expedition to Baffin Island, brought back over 1000 tonnes of a shiny yellow mineral that looked like gold. Unfortunately it was not – it was fool's gold which is actually an ore of iron. The ore is called iron pyrites and it is mainly made up of iron sulphide.

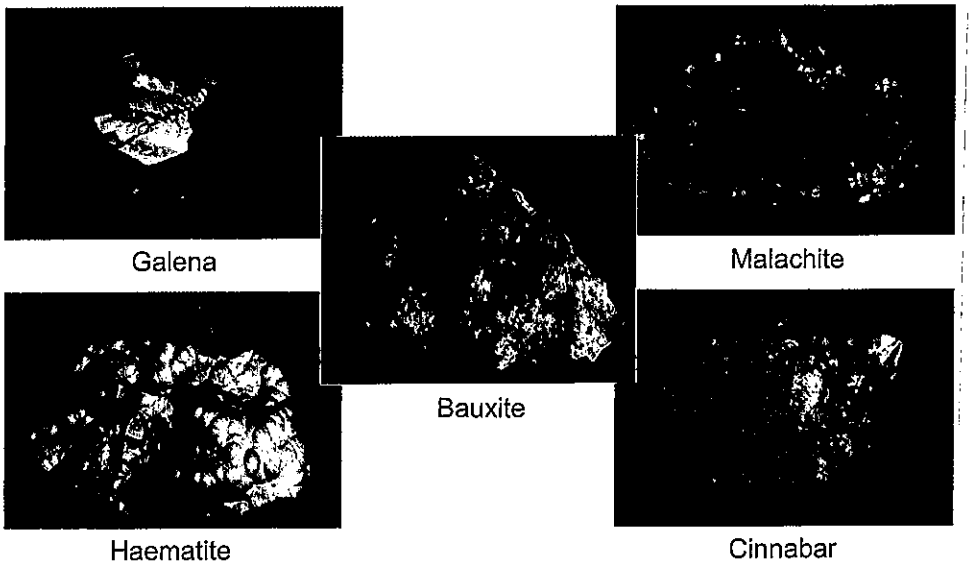


Figure 3.2 *Common metal ores.*

Some common examples of ores are:

- haematite, an ore of iron, is mainly iron oxide
- bauxite, an ore of aluminium, is mainly aluminium oxide
- galena, an ore of lead, is mainly lead sulphide
- cinnabar, an ore of mercury, is mainly mercury sulphide
- malachite, an ore of copper, is mainly copper carbonate
- limestone, an ore of calcium, is mainly calcium carbonate.

There are two basic steps involved in obtaining a metal from its ore:

- mining and collecting the ore
- **decomposition** of the compounds in the ore to release the metal.

Micro-organisms extract 10% of all the copper produced in the USA. Bacteria like *Thiobacillus ferro-oxidans* obtain the energy they need for life by reducing the copper ore, chalcopyryte, to copper. Extracting copper by this method is much cleaner and cheaper than using other industrial methods.

Extracting metals from ores

The extraction of a metal from its ore involves a chemical reaction to release the metal from its compounds. The more reactive metals form the most stable compounds which are hardest to break down. This explains why the least reactive metals were the first metals to be extracted in large quantities. For example, copper can be extracted from its ore malachite by heating in a charcoal fire. After gold and silver, copper was one of the first metals to be used. Other methods had to be found to decompose the ores of more reactive metals.

The extraction of a metal from its ore is an example of a decomposition reaction. However, it can also be described as a **reduction** reaction, because the ore is **reduced** (broken down) to release the metal. During reduction, the elements combined with the metal are removed and the metal is left free. Many ores are oxides so this means removing oxygen to release the metal.

There are three main methods, that can be used to reduce metal ores and extract metals:

- heat alone
- heat with carbon
- electrolysis.

The industrial process chosen to extract a particular metal has to be the most economic. Therefore, the method used will be the one which works, and is least expensive.

1 What kind of compounds are commonly found in metal ores? *[Total 1]*

2 Which factors help in deciding how metals are extracted from their ores? *[Total 2]*

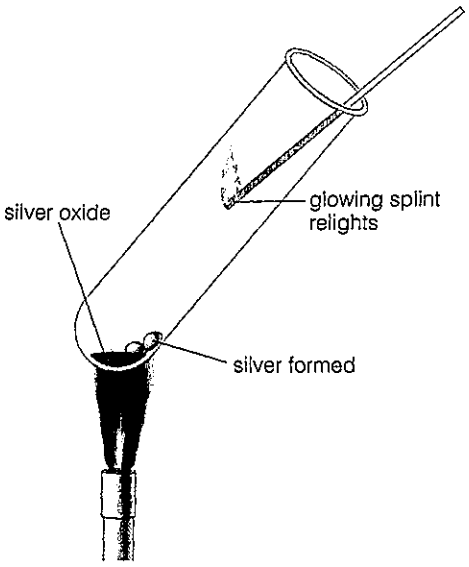


Figure 3.3 *Decomposing silver oxide.*

Extraction by heat alone

Heat alone can reduce some of the least stable metal ores to release the metal. Only the least reactive metals can be extracted using this method. For example silver is often found in an ore which contains silver oxide. If it is heated it is reduced, and silver metal and oxygen gas are formed. The reduction of silver oxide is shown in Figure 3.3.

Beads of silver metal can be seen at the bottom of the test tube and the formation of oxygen can be shown as it relights a glowing splint. The word equation is:

$$\text{silver oxide} \xrightarrow{\text{heat energy}} \text{silver} + \text{oxygen}$$

Mercury and silver are usually extracted by **thermal decomposition**. These are two of the less reactive metals, which are found near the bottom of the reactivity series. However, many metal oxides cannot be decomposed by heat alone, and other methods have to be used to extract the metal.

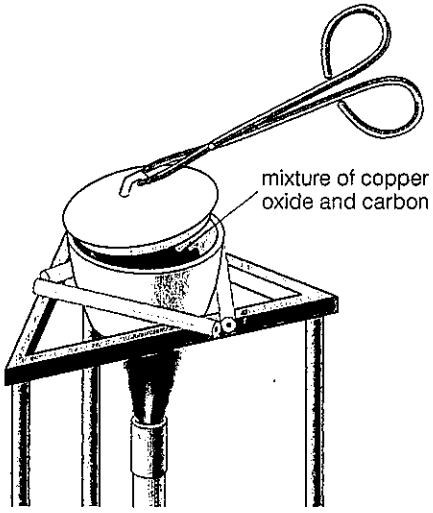


Figure 3.4 *Extraction of copper by heating with carbon.*

Extraction by heating with carbon

Many ores are metal oxides, and most others can be converted to their oxides by roasting in air. Heating a metal oxide with carbon is another method that can be used to extract metals.

For example, if copper oxide is heated with carbon powder, the oxide is reduced, forming copper metal and carbon dioxide gas. The word equation is:

$$\text{copper oxide} + \text{carbon} \xrightarrow{\text{heat energy}} \text{copper} + \text{carbon dioxide}$$

The carbon acts as a **reducing agent**, taking the oxygen away from the metal. The carbon and oxygen combine to form carbon dioxide, and the metal is left free. This is a reduction reaction, because the metal oxide is reduced to release the metal.

Zinc, iron, nickel, tin, lead and copper are usually extracted by heating with carbon. These are metals of moderate reactivity, which are found in the middle of the reactivity series. The reaction is similar to the displacement of a metal from one of its compounds, which was dealt with in the last subsection. Carbon is more reactive than these metals and so can displace them from their oxides.

3 What is a reducing agent? *[Total 1]*

Extraction by electrolysis

Passing electricity through a molten ore will split up the compound, and so extract the metal. This process is called **electrolysis**. The electrical energy decomposes the compounds and reduces the ore.

For example, aluminium is extracted by the electrolysis of molten bauxite, which consists mainly of aluminium oxide. During electrolysis, the ore is reduced, aluminium forms at the negative electrode and oxygen is produced at the positive electrode.

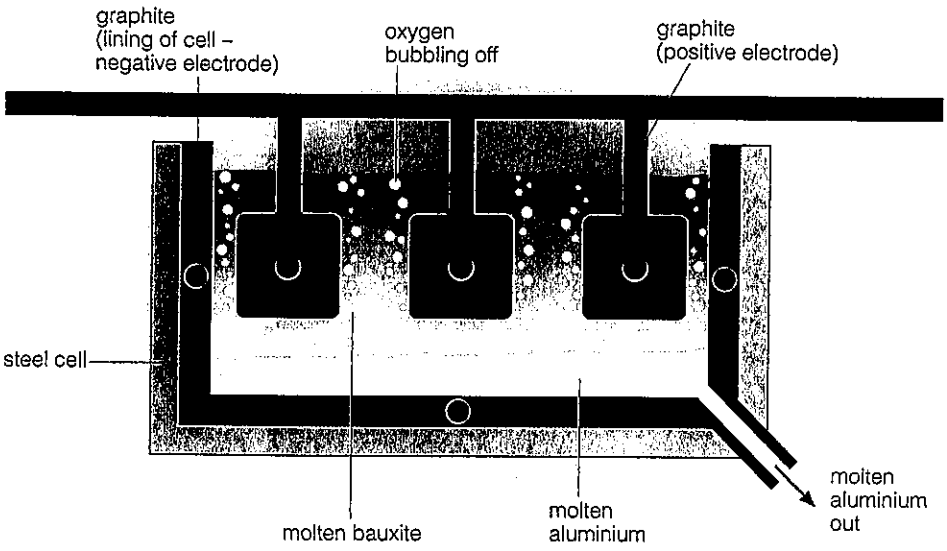


Figure 3.5 *Extraction of aluminium by electrolysis.*

The reduction reaction involves breaking up the aluminium oxide:

$$\text{aluminium oxide} \xrightarrow{\text{electrical energy}} \text{aluminium} + \text{oxygen}$$

Remember, the metal is always formed at the negative electrode during electrolysis. As electrolysis requires large quantities of electricity, it is a very expensive process. Therefore, it is only used when no other method will work. Potassium, sodium, calcium, magnesium and aluminium are all usually extracted by electrolysis. These represent the most reactive metals, which are found at the top of the reactivity series.

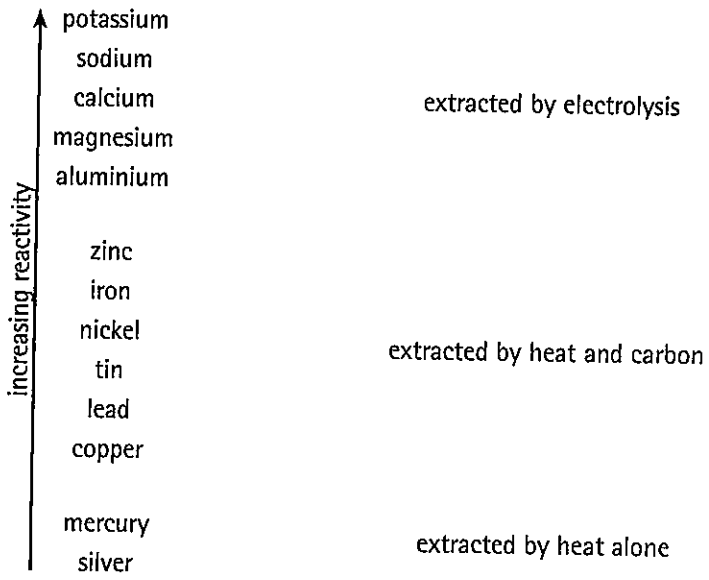
Electrolysis is the only way of reducing these ores because they contain the most stable compounds.

For other metals, thermal decomposition or heating with carbon is used because it is cheaper. A summary of methods of extraction is given in Table 5.1.

Copper was probably discovered by chance when people were making coloured vases. 5000 years ago potters used glazes containing coloured copper compounds. These could have been accidentally reduced to copper by the carbon in the fires.

4 Why aren't all metals extracted by electrolysis? *[Total 2]*

Table 5.1 *Methods of extraction.*



5 Magnesium can displace iron from iron oxide. Suggest why this is not done on an industrial scale to produce iron.

[Total 3]

Summary

Only the least reactive metals like gold, silver and platinum are found in a native state (as elements).

Rocks from which metals can be extracted are called ores.

Decomposition reactions involve breaking down compounds.

Metals are extracted from compounds in their ores by a reduction reaction.

The less reactive metals are extracted by heat alone.

The metals of moderate reactivity are extracted by heating with carbon.

The most reactive metals can only be extracted by electrolysis.

Questions

1 Copy and complete the following sentences.
The metals silver, _____ and _____ are found uncombined in nature. Most metals are found combined with other _____ in rocks called _____. Bauxite, galena and _____ are examples of metal _____.
[Total 3]

2 Write one sentence for each of the following phrases to explain what each means:
a) reduction reaction *[2]*
b) native metal. *[2]*
[Total 4]

3 a) What is an ore? *[1]*
b) Give an example of a word equation for a decomposition reaction which forms a metal oxide and carbon dioxide. *[2]*
c) Which common method of extracting metals is most expensive? *[1]*
[Total 4]

4 Copy and complete the table below to show the method used to extract each of the metals from their oxides. *[Total 3]*

Table 5.2

Metal oxide	Main method used to extract metal
nickel oxide	
calcium oxide	
mercury oxide	
iron oxide	
magnesium oxide	
lead oxide	

5 Write a word equation for each of the following chemical reactions:
a) reducing zinc oxide with carbon *[2]*
b) breaking down mercury oxide with heat alone. *[2]*
[Total 4]

6 Explain why, in Britain, the **Bronze Age** started about 1500 BC but the **Iron Age** did not start until 500 BC (**bronze** is an alloy of copper and tin). *[Total 2]*

7 Suggest why aluminium, the most abundant metal, was worth more than gold in 1820. *[Total 2]*

8 Read this passage carefully before answering the questions which follow.
Metals are used everywhere and they are one of our most precious resources. Most metals are extracted from ores, but supplies of metal ores are running out. Calculations show that at the present rate of use, we have about enough reserves of aluminium for 250 years, copper for 30 years, lead for 20 years and nickel for 50 years. We must stop wasting our precious reserves of metals. Much of what we throw away could be reused. Recycling metals would save our resources for future use. In addition, large quantities of energy are needed to extract metals from their ores, so recycling would also reduce the amount of energy we use to produce the metals.
a) Which metal has the largest reserves? *[1]*
b) What does recycling mean? *[1]*
c) Describe two advantages of recycling metals. *[2]*
d) Draw a bar chart showing the number of years left for each of the metals mentioned in the passage. Remember to give names and units where appropriate. *[4]*
[Total 8]

9 Imagine your friend has missed the lesson on extracting metals. Draw up a poster, using labelled diagrams, equations and tables, to summarise 'Finding and extracting metals'. *[Total 8]*