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CHAPTER ELEVEN
Metals

SECTION 11.1 Properties of metals

We are surrounded by metals. Some are easy to see, such as car bodies, steel bridges, etc. Others are present in only tiny amounts. For example, tungsten metal is used in the tips of ball-point pens and in the wire filaments inside light bulbs. Computers contain small amounts of gold in their electrical connections.

We can use metals for so many different jobs because of their **properties**. Some of the most important properties of metals are:

- **Strength** – metals that are strong are used for bicycle frames, railway lines, ships' hulls, etc. Special steels are used for armour-plating in tanks.
- **Malleability** – metals are malleable. This means that they can be hammered and rolled into flat sheets or different shapes. Think about the way gold can be shaped into intricate chains and rings.
- **Conduction of electricity** – all metals are conductors of electricity. Copper wires are commonly used in household cables and flexes in electrical appliances. Aluminium cables carry the electricity in the National Grid.
- **Conduction of heat** – we use metals for making cooking pots and pans because they are able to conduct the heat from the cooker to the food inside. If you look on the back of a fridge you will see a metal grill. Its job is to conduct heat away from the fridge, keeping it cool.
- **Density** – this is the mass of a substance in a given volume. A high density material is much heavier than the same volume of a low density material. Aluminium is a metal with a low density. It is used to build aircraft bodies. Lead, with its high density, is used as weights for some fishing nets and lines.

Figure 1.1 These guitar strings are made from a metal containing nickel and copper

Questions

Q1 Look at figure 1.1. The guitar strings are made of a metal containing copper and nickel. What properties do they need to have?

Alloys

The properties of metals can be changed and improved by making **alloys**. Most alloys are mixtures of two or more metals, but in a few cases non-metals are also added. The usual way to make an alloy is to melt together the elements that make it up. Pure gold is very soft. Eighteen carat gold, which is used in some jewellery, is a harder metal made of an alloy of gold and copper. Modern coins are alloys. A £1 coin is an alloy of copper, nickel and zinc.

Figure 1.2 These coins are made from alloys

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Coin	Made from...
'copper'; 1p, 2p	copper-coated steel
'silver'; 5p, 10p, 20p, 50p	alloy of copper and nickel
'gold'; £1	alloy of copper, nickel and zinc

Table 1.1 What our coins are made of

Alloy	Made from...
brass	copper and zinc
bronze	copper and tin
solder	lead and tin

Table 1.2 Some other alloys

Steels are alloys in which the main metal element is iron. They are usually much stronger than pure iron. Mild steel, an alloy of iron and carbon, is widely used in the construction industry. However, this alloy rusts easily. Stainless steel is much more rust-resistant because there is a small amount of chromium metal present in the alloy.

Figure 1.3 Recycling aluminium cans

Recycling metals

Recycling aluminium saves energy and money. To make a can from recycled aluminium can take only 5 per cent of the energy required to make one from new aluminium. This is because of the large amounts of electricity needed to produce new aluminium. Saving electricity also means that less fuel is burned in power stations. Large quantities of the greenhouse gas carbon dioxide are produced when aluminium is manufactured – recycling means less carbon dioxide is added to the atmosphere. Steel cans can also be recycled.

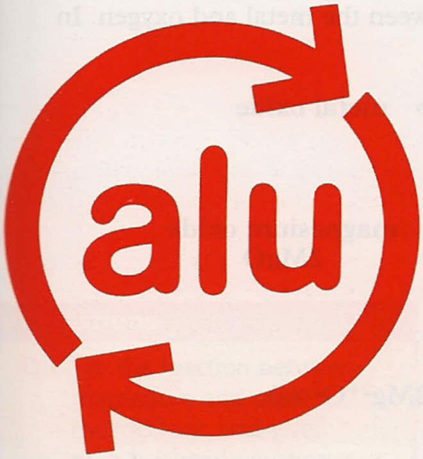

Figure 1.4 You may have seen this logo on aluminium cans. What does it mean?

Questions

Q2 Give at least four reasons why recycling metals is good for the environment.

Another reason for recycling metals is that the world is running out of certain metals. There is only a finite amount of each metal in the world.

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SECTION 11.2 The reactivity of metals

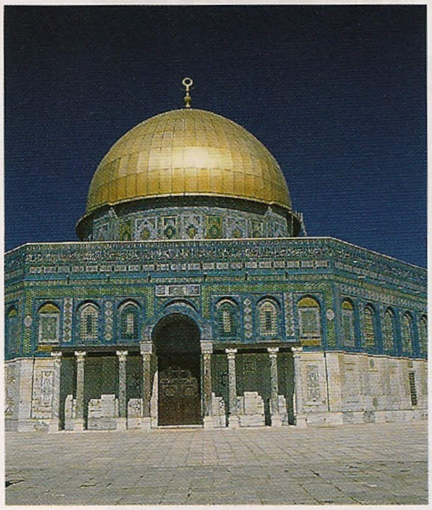

Figure 2.1 Why has the golden dome on this mosque stayed shiny for so long?

A reactivity series of metals

Some metals react very quickly and easily with the oxygen in the air. For example, a new piece of sodium metal will react with oxygen to form a layer of sodium oxide in about 30 seconds. However, copper takes many *years* to react with oxygen. You may also have noticed that gold does not react with the oxygen in the air at all. The golden dome of the mosque in figure 2.1, for example, has not reacted with the oxygen in the air even after hundreds of years.

From the observations above, we can put the three metals sodium, copper and gold in order of **reactivity**. We can say that sodium is more reactive than copper, which is more reactive than gold.

Chemists have produced a **reactivity series** – a kind of 'league table of metals' which puts them in order of reactivity. Table 2.1 shows a reactivity series.

In the reactivity series, the metals nearest the top are the most reactive. The reactivity of the metals decreases as you go down the series. Notice that the order of the metals in the reactivity series is very similar to that in the electrochemical series (see section 10.2).

Name	Symbol
potassium	K
sodium	Na
lithium	Li
calcium	Ca
magnesium	Mg
aluminium	Al
zinc	Zn
iron	Fe
tin	Sn
lead	Pb
copper	Cu
mercury	Hg
silver	Ag
gold	Au

Table 2.1 A reactivity series of metals

Reaction with oxygen

All of the metals above silver in the reactivity series combine with oxygen when heated. This produces a metal oxide. The higher a metal is in the series, the more violent the reaction is between the metal and oxygen. In general, this reaction takes the form:

$$\text{metal} + \text{oxygen} \rightarrow \text{metal oxide}$$

For example,

$$\text{magnesium} + \text{oxygen} \rightarrow \text{magnesium oxide}$$
$$2Mg + O_2 \rightarrow 2MgO$$

Equation showing ions and state symbols:

$$2Mg(s) + O_2(g) \rightarrow 2Mg^{2+}O^{2-}(s)$$

The apparatus shown in figure 2.2 can be used to study the reactivities of metals from magnesium down to copper in the reactivity series.

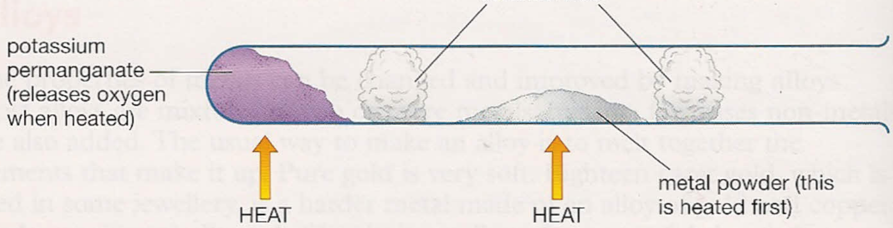

Figure 2.2 Metals glow brightly as they react with oxygen

The three metals at the top of the reactivity series – potassium, sodium and lithium – are so reactive they are stored under oil to prevent them from reacting with oxygen and water in the air.

Questions

Q1 a) Write a balanced equation for the reaction between potassium and oxygen.
b) Write an equation showing the ions present in the reaction. Use the equations given above as a guide.

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Reaction with water

The metals above aluminium in the reactivity series react with water to produce hydrogen gas and the corresponding metal hydroxide. The general equation for this is:

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

For example,

$$\text{sodium} + \text{water} \rightarrow \text{sodium hydroxide} + \text{hydrogen}$$
$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

Equation showing ions and state symbols:

$$2Na(s) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$$

Questions

Q2 For the reaction between calcium and water, give:
a) a balanced equation,
b) an equation showing ions and state symbols.

Reaction with dilute acids

All metals above copper in the reactivity series react with dilute acids such as hydrochloric acid and sulphuric acid to produce a salt and hydrogen:

$$\text{metal} + \text{acid} \rightarrow \text{salt} + \text{hydrogen}$$

For example,

$$\text{zinc} + \text{hydrochloric acid} \rightarrow \text{zinc chloride} + \text{hydrogen}$$
$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Equation showing ions and state symbols:

$$Zn(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow Zn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$$

When a metal reacts with an acid it produces bubbles of hydrogen gas. In most cases, the faster the bubbles are produced, the more reactive the metal. One exception is aluminium. It reacts slowly with acids for about the first 20 minutes, after which it reacts quickly. The reason for this is that it is protected by a thin layer of aluminium oxide, which must first be removed by the acid.

Table 2.1 summarises the reactions of metals.

Questions

Q3 For the reaction between magnesium and dilute hydrochloric acid, give:
a) a balanced equation,
b) an equation showing ions and state symbols.

Q4 A, B and C are three metals. Metal A reacts with dilute hydrochloric acid but not with water. Metal B does not react with water or dilute acid. Metal C reacts with water and dilute acid.
a) Place the metals in order of reactivity, with the most reactive first.
b) Using the reactivity series in table 2.1, give all the possible metals that A, B and C could be.

<table>
<tr><th rowspan="2">Metal</th><th colspan="3">Reaction with</th></tr>
<tr><th>Oxygen</th><th>Water</th><th>Diluted acid</th></tr>
<tr><td>potassium</td><td rowspan="11">metal
+
oxygen
↓
metal oxide</td><td rowspan="5">metal + water
↓
metal hydroxide
+ hydrogen</td><td rowspan="10">metal
+
acid
↓
salt
+
hydrogen</td></tr>
<tr><td>sodium</td></tr>
<tr><td>lithium</td></tr>
<tr><td>calcium</td></tr>
<tr><td>magnesium</td></tr>
<tr><td>aluminium</td><td rowspan="9">no reaction</td></tr>
<tr><td>zinc</td></tr>
<tr><td>iron</td></tr>
<tr><td>tin</td></tr>
<tr><td>lead</td></tr>
<tr><td>copper</td><td rowspan="4">no reaction</td></tr>
<tr><td>mercury</td><td rowspan="3">no reaction</td></tr>
<tr><td>silver</td></tr>
<tr><td>gold</td></tr>
</table>

Table 2.1 Reactions of metals