CORROSION OF METALS

Corrosion is a chemical reaction which involves the surface of a metal changing from an element to a compound. The more reactive the metal the quicker it corrodes. Many of the more reactive metals, including Iron, are lost through corrosion.

EXAMPLE 1

Aluminium corrodes slowly in air :

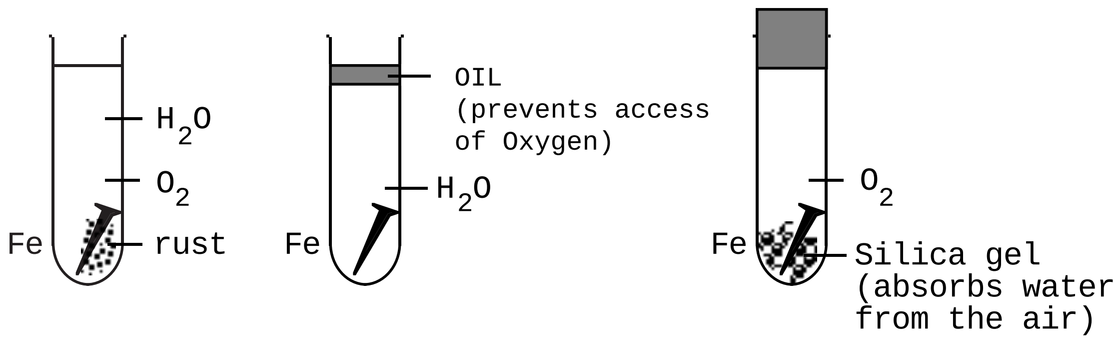
$Al + O_2 \rightarrow Al_2O_3$

EXAMPLE 2

Iron corrodes slowly in moist air (Rusting).

What happens during rusting?

Both **OXYGEN AND WATER** are required as the following experiment shows :



RUSTING **NO RUSTING** **NO RUSTING**

This is what happens to the Iron :

Iron is oxidised in two stages :

$Fe \rightarrow Fe^{2+} + 2e$

$Fe^{2+} \rightarrow Fe^{3+} + e$

The electrons lost by the Iron are picked up by the Oxygen and Water which are therefore reduced in the process :

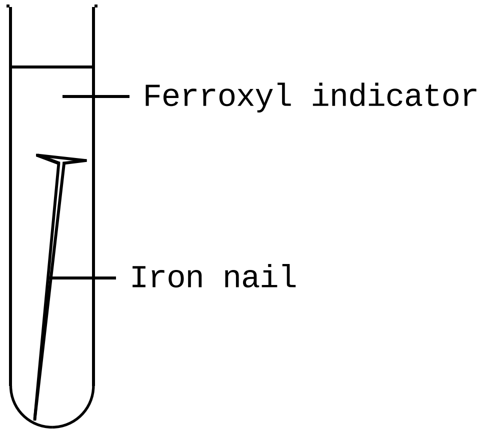
$O_2 + 2\ H_2O + 4e \rightarrow 4\ OH^-$

Hydroxide ions react with Iron(III) ions to form the brown precipitate, Iron(III) hydroxide (rust ?) :

$Fe^{3+} + 3\ OH^- \rightarrow Fe^{3+}(OH^-)_3$

EXPERIMENT

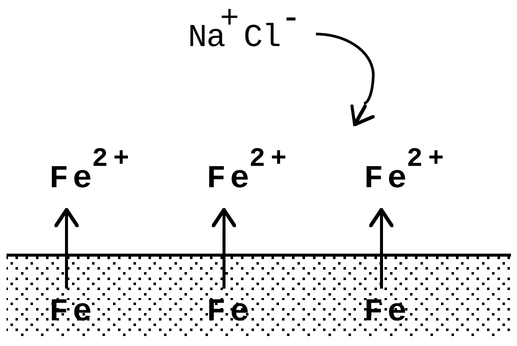
Place an Iron nail in Ferroxyl indicator solution.



Ferroxyl indicator turns BLUE in the presence of Fe^{2+} ions. A BLUE colour appears round the Iron showing that Fe^{2+} are formed.

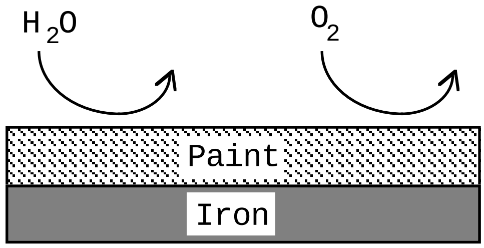
Ferroxyl indicator turns PINK in the presence of OH^- ions. A PINK colour should appear round the Iron showing that OH^- are formed. The pink colour is usually swamped by the intense blue colour and difficult to see.

Salt (Sodium chloride Na^+Cl^-) spread on roads, increases the corrosion rate of car bodywork. As Iron corrodes an area of positive charge builds up around its surface due to the Iron(II) ions. This repels any additional Iron(II) ions which try to form and thus slows down corrosion. The chloride ions, from the Sodium chloride, diffuse into the area of positive charge around the Iron, cancelling out the charge and allowing more Iron(II) ions to form e.g.

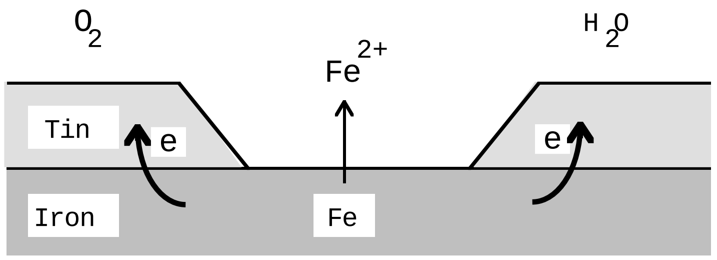


PREVENTING CORROSION

Rusting can be prevented by stopping the Oxygen and Water from getting to the Iron using a barrier e.g. oil, grease, paint, plastic or metal :



Plating with Tin is a common example of the 'barrier' method. It has one drawback. If the Tin layer cracks then Oxygen and Water can get to the Iron. A cell developes: electrons flow from the most reactive metal (Iron) to the least reactive metal's ions (Tin (II)). This allows the Iron to form ions and corrode.



Corrosion is more rapid than in an uncoated piece of Iron : the Tin(II) ions pull electrons off the Iron :

$Fe \rightarrow Fe^{2+} + 2e$

$Sn^{2+} + 2e \rightarrow Sn$

We can, however, learn from this disaster. We can develop an electrical method of preventing corrosion.

Electrons are lost during the first step in the corrosion of Iron :

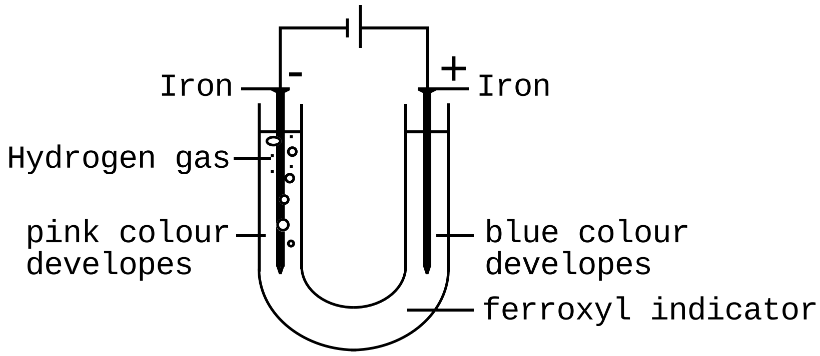
$Fe \rightarrow Fe^{2+} + 2e$

If we force these electrons back on to the Iron we will reverse the first step.

$Fe^{2+} + 2e \rightarrow Fe$

This can be done in **TWO** ways :

1. Connecting the Iron to the negative terminal of a battery:



At the anode (+ve) electrons are pumped away from the Iron, speeding up the corrosion rate :

$Fe \rightarrow Fe^{2+} + 2e$

and leading to the production of Fe^{2+} ions which turn the indicator blue.

At the cathode (-ve) electrons are pumped on to the Iron, slowing down the corrosion rate. NO Iron(II) ions are produced so NO blue colour appears. Instead a pink colour appears !

Remember that Water, due to its ionisation, contains H^+ ions.

$H_2O \rightleftharpoons H^+ + OH^-$

As the electrons are pumped on to the Iron the excess electrons 'spill over' into the solution where they are picked up by H^+ ions in the Water :

$2H^+ + 2e \rightarrow H_2$

Removal of the Hydrogen ions from Water leaves excess hydroxide ions. Hydroxide ions turn Ferroxyl indicator pink.

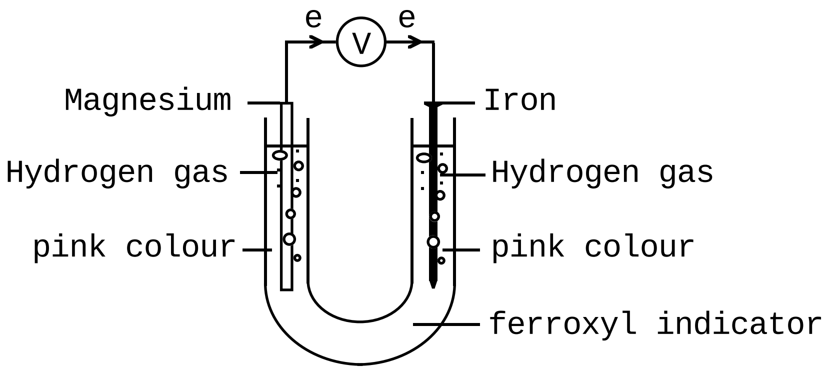
2. By connecting the Iron to a more reactive metal (e.g. Magnesium)

Electrons flow from the more reactive metal (Magnesium) to the less reactive metal's ions (Iron(II)) thus preventing loss of electrons by Iron :

$Mg \rightarrow Mg^{2+} + 2e$

$Fe^{2+} + 2e \rightarrow Fe$

The direction of electron flow can be shown with a cell :



NO blue colour appears round the Iron so no Iron(II) ions are being produced.

Excess electrons are captured by Hydrogen ions in the Water forming Hydrogen gas :

$2 H^+ + 2e \rightarrow H_2$

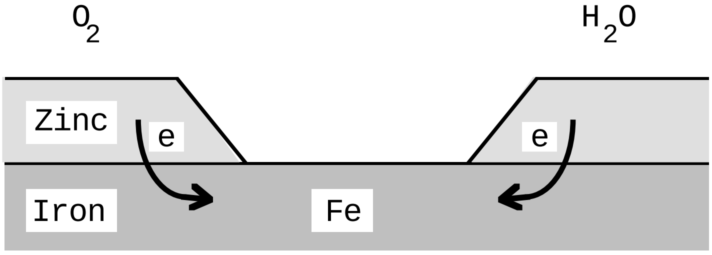
This leaves excess OH^- ions which turn the indicator pink.

Magnesium scrap is connected to oil pipelines made of Iron to prevent corrosion.

Notice that, as a result of protecting the Iron, the Magnesium loses electrons, forms ions and corrodes itself.

The Magnesium therefore sacrifices itself to save the Iron (Sacrificial Protection).

Galvanising (coating with Zinc) is the most common use of sacrificial protection. If the Zinc layer cracks:



the Oxygen and Water can get to the Iron but corrosion still does not occur because electrons flow from Zinc to Iron preventing loss of electrons by Iron. Bridge girders are galvanised.