# Controlling Rust

*Contents:* Information, questions and decision-making exercises concerning rusting and its prevention, in particular its economic aspects.

*Time:* 2 periods.

*Intended use:* GCSE Chemistry and Integrated Science. Links with work on rusting, iron and the reactivity series of metals.

*Aims:*

- To complement and revise prior work on rusting, iron and the reactivity series.
- To develop awareness of the economic impact of corrosion, and factors involved in selecting an appropriate method of corrosion control.
- To develop awareness of some of the factors involved in commercial decision-making.
- To provide an opportunity to practise reading, comprehension and data-handling skills.

*Requirements:* Students' worksheets No. 103.

This unit is in four parts:

Part 1 Information on rusting and prevention methods
Part 2 Decisions – which method to use?
Part 3 More decisions – protecting the school bridge
Part 4 More points to discuss.

It is assumed that this unit will be used in conjunction with more conventional class work on rusting, probably including some experimental work. If so, Part 1, which is only a summary, could be omitted, or perhaps covered for homework. Nevertheless, students should cover the short introductory section on the cost of rust, to put the problem in perspective.

Part 4 could also be omitted if time is short, though it raises some interesting discussion points.

For simplicity, no mention is made in the unit of the use of *alloying* to prevent rust. The teacher may want to mention this, and to refer to stainless steel.

Less able students may need some guidance when tackling the decision-making exercise in Part 3. It might help them to draw up a table like the one below, in which to enter the various costs year by year.

| *Year* | *Option 1* | *Option 2* | *Option 3* | *Option 4* |
|---|---|---|---|---|
| 0 | | | | |
| 1 | | | | |
| 2 | | | | |
| . | | | | |
| . | | | | |
| Total | | | | |

## Other resources

The National Corrosion Service of the National Physical Laboratory have produced a booklet called *Corrosion and Protection of Metals – Information for Use by Teachers*, and a set of slides. Available from:

National Corrosion Service
National Physical Laboratory
Teddington
Middlesex TW11 0LW

*Acknowledgement* Photo on page 1 Chris Ridgers Photography

# CONTROLLING RUST

This unit is about the rusting (or corrosion, as it is sometimes called) of iron and steel. Why does rusting occur? How much does it cost – and how can it be prevented?

## The cost of rust

It is thought that rusting costs Britain about £5000 million each year. This is more than the total amount spent by the Government on secondary education!

*Look at these examples*

- 40% of the steel made in the USA is used to replace steel lost by rusting.
- The steelwork on the Spaghetti Junction motorway interchange has to be painted continually to prevent rust. This costs about £2 million over an 18-month period.

*Question*

1 *How many tonnes of steel are lost by rusting per year in Britain?*

It is thought that one tonne of steel is lost by rusting every 90 seconds in Britain.

*Cars are particularly badly affected by rust.*

## Part 1 Information

You may already have done quite a lot of work on the causes of rust, and how it can be prevented. If so, you could miss this part and go straight on to Part 2.

### What causes rust?

You may have done experiments to investigate what causes rust. These experiments will have shown you that two things are needed:

WATER and AIR

Without both of these, rusting does not occur. If the water contains dissolved impurities, such as salt, rusting is faster.

Rusting is a very complicated reaction, but the end result is simple. Iron is oxidized to form iron oxide, $Fe_2O_3$, which is rust.

IRON + OXYGEN $\xrightarrow{\text{water}}$ IRON OXIDE (RUST)

When iron is manufactured, it is made by taking away oxygen from iron ore. This is reduction. So rusting is really just returning iron to its naturally-occurring form, iron oxide (Figure 1). This is a neat way of getting rid of unwanted iron, but it can be a real nuisance!

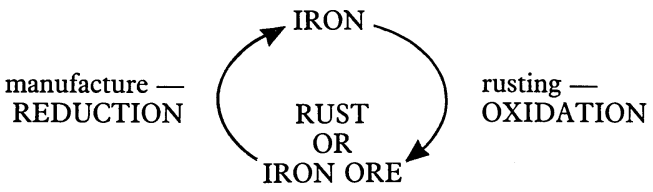


*Figure 1 Iron, rust and iron ore.*

*Questions*

2 *Why does painting the surface of iron prevent rust?*

3 *Why does iron rust especially badly in seaside areas?*

## Preventing rust

There are many different ways of preventing rust, and some are better than others. The different methods also vary a lot in cost.

1. *Surface protection*
   Rusting needs air and water. If these can be kept away from the metal surface, rusting will not occur. Surface protection can be given in several ways.

   (a) *By covering with oil or grease* This is not very effective, because the oil or grease soon rubs off.
   (b) *By painting* Paint keeps out water and air, but as soon as the paint cracks or peels off, rusting begins (Figure 2).

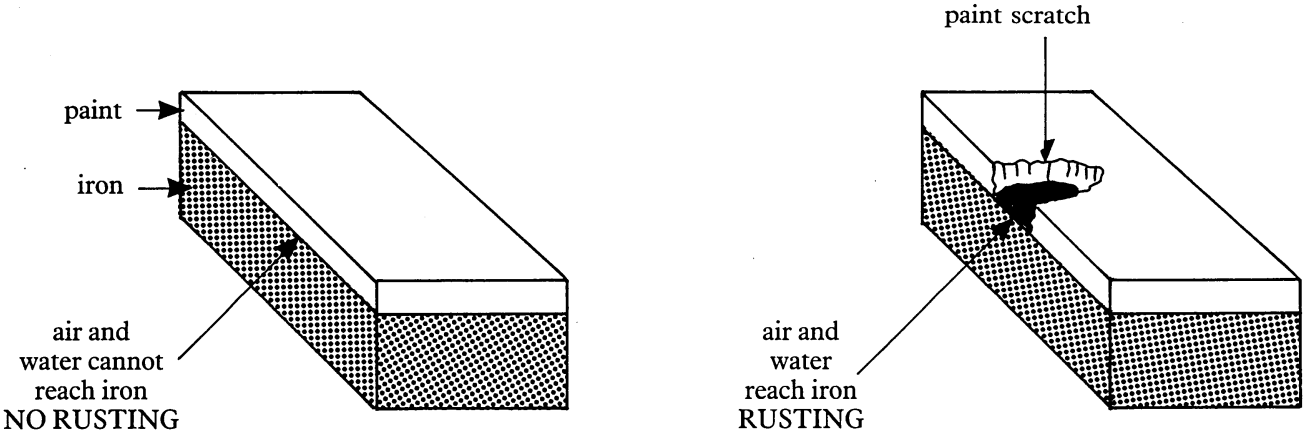


*Figure 2 Protecting iron by painting*

Then the metal must be painted again. Paint lasts longer if it is put on a really clean surface. Any traces of water, oil or rust make the paint peel off more easily. The best way of cleaning a metal surface for painting is by sand-blasting.

(c) *By covering with plastic* Wire is often protected this way.
(d) *By plating with metal* Iron can be coated, or plated, with another metal to prevent rust. If the metal is less reactive than iron, it just protects it like a coat of paint. Metal plating often looks decorative: for example, iron is chromium plated to make it look shiny.

2. *Sacrificial protection*
Some metals are more reactive than iron. Zinc and aluminium are examples of such metals. If iron is covered with a reactive metal like zinc, it gets extra rust protection. Oxygen prefers to react with the zinc, and this stops it reacting with the iron. Because the zinc is sacrificed to protect the iron, it is called a **sacrificial coating**. Even if some of the zinc gets scratched off, the iron is still protected (Figure 3). However, if iron is coated with a *less* reactive metal, like tin or chromium, it loses its protection once the coating is scratched.

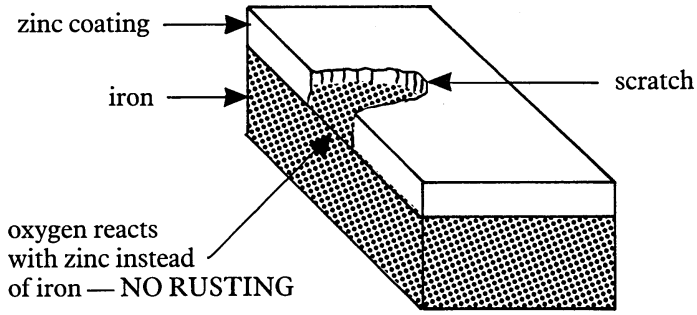


*Figure 3 Protecting iron by sacrificial coating*

*Questions*

This list shows some of the metals used to protect iron, in order of reactivity.

magnesium
aluminium
zinc
cadmium
(iron)
tin
nickel

4 *Which metal in the list do you think would give the best sacrificial protection? Explain your answer.*

5 *Which metals in the list would give no sacrificial protection at all?*

## Part 2 Decisions – which method to use?

The chart in Figure 4 compares the effectiveness of different ways of stopping rust. It also gives their costs, though these are very approximate.

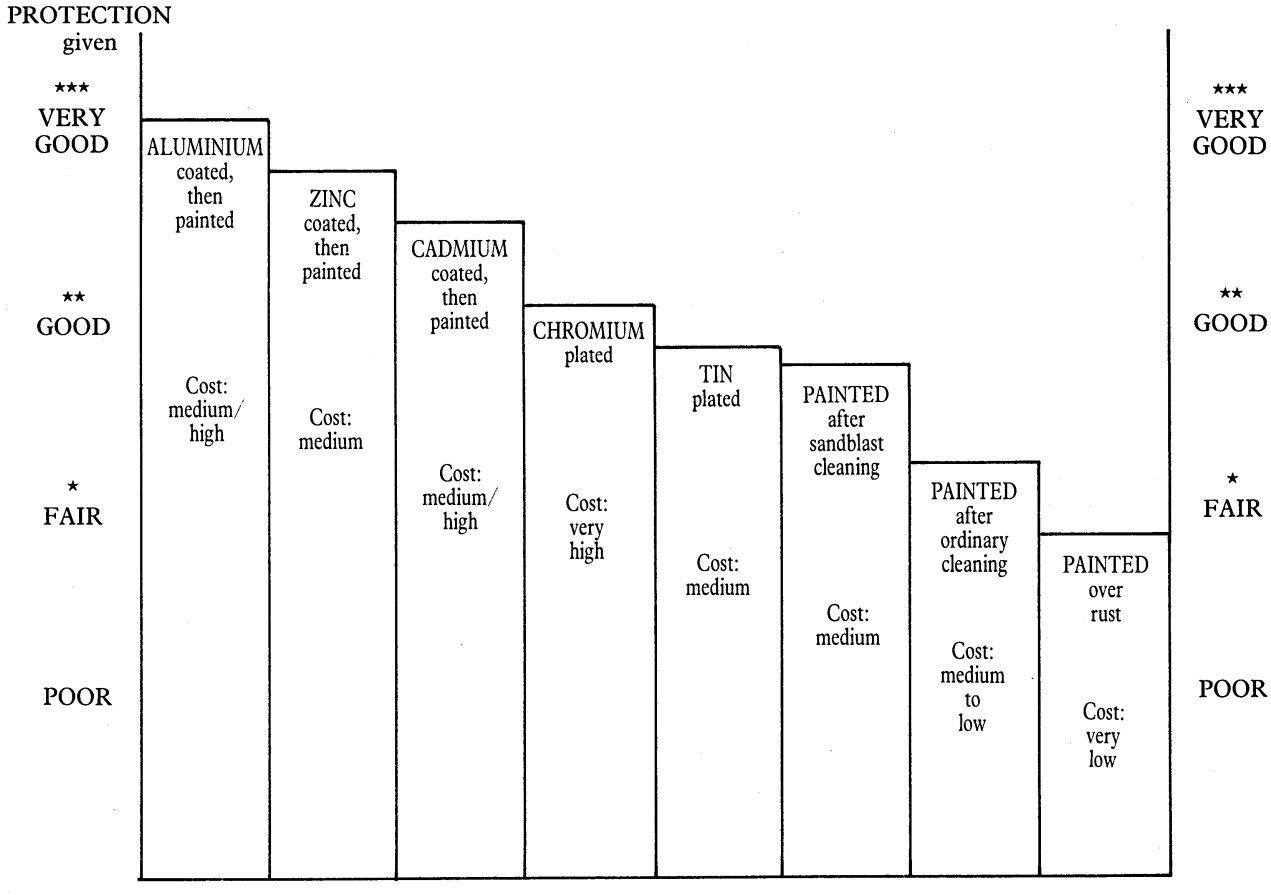


*Figure 4 Comparing the effectiveness and cost of different rust prevention methods*

In questions 6 to 12 you are asked to decide which rust prevention method to use in different cases. It is best to work in small groups on these questions. These are some of the facts you should bear in mind.

- How long does the article need to last? Obviously if it has a short lifetime, there is no point in giving it long-lasting protection.
- Where will the article be used? If it is to be used a lot outside, it will need better protection.
- What is the article to be used for? Different kinds of protection are suitable for different jobs. For example, paint is no use for an article that will get very hot.
- Is appearance important? Some kinds of protection are also decorative (chromium plating, for example).

*Questions*

Decide which method you would use to protect each article against rust. Look back at the chart in Figure 4 to find out costs and effectiveness before you decide which method to choose.

If you think there are other possibilities as well as rust prevention, say so. (For example, in question 6 you might say 'replace it with a plastic gutter'.)

6 *A cast-iron gutter on a house*
7 *Steel railings on a seaside pier*
8 *An iron badge*
9 *The base of an electric iron*
10 *A steel knife blade*
11 *An iron key*
12 *The steel frame of a swing in a children's playground.*

## Part 3 More decisions – protecting the school bridge

You work for the Bridges Department of the local council. You have to build a footbridge across a river so children from a housing estate can reach the local school (Figure 5).

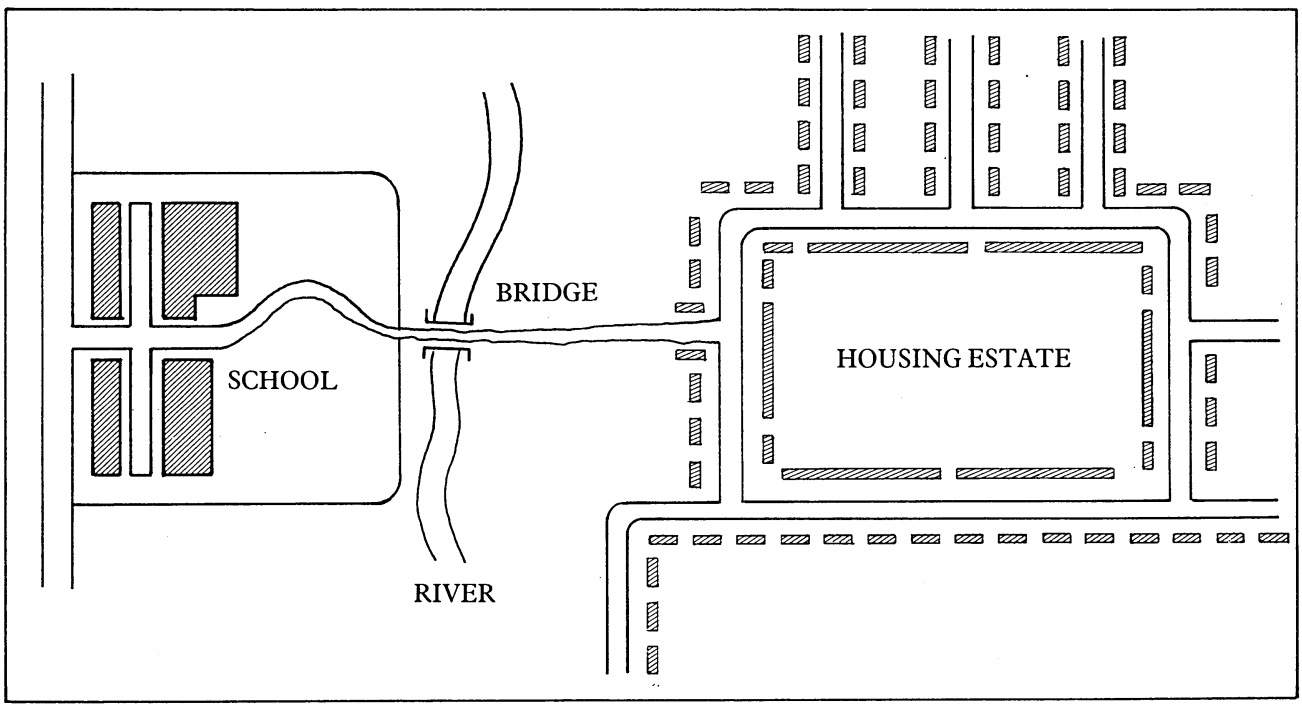


*Figure 5 Map showing location of bridge*

The bridge is to be made of iron, and you have to decide how to protect it against rust. It does not need to last more than 16 years, because after that time the school is due to move to a new site.

You have four options concerning rust protection:

*Option 1:* No protection. With no protection the bridge will need replacing after 10 years due to dangerous corrosion.

*Option 2:* Paint the bridge, after ordinary cleaning of the metal. It will need cleaning and repainting every 3 years.

*Option 3:* Paint the bridge, after cleaning the metal by sandblasting. It will need sandblasting and repainting every 6 years.

*Option 4:* Clean the metal by sandblasting, then zinc coat it, then paint it. This protection will last 18 years.

Table 1 gives information about the costs of these options.

*Questions*

*13 For each option, work out the cost of building and maintaining the bridge for 16 years.*

*14 Apart from cost, are there any other factors you should consider before you decide?*

*15 Which option would you choose?*

*Table 1 Costs of the four options*

| | *Option 1* (no protection) | *Option 2* (ordinary cleaning and painting) | *Option 3* (sandblasting and painting) | *Option 4* (sandblasting and zinc coating and painting) |
|---|---|---|---|---|
| Cost of the basic bridge | £40 000 | £40 000 | £40 000 | £40 000 |
| Cost of installing the bridge | £ 5000 | £ 5000 | £ 5000 | £ 5000 |
| Rust protection costs: | None | | | |
| 1. Cleaning the surface | | £ 600 | £ 2000 | £ 2000 |
| 2. Coating the surface | | £ 3000 | £ 3000 | £ 5000 |
| Value of the bridge as scrap | £ 800 | £ 800 | £ 800 | £ 800 |

## Part 4 More points to discuss about rusting

- Only iron and steel suffer from rust. Many other metals exist which hardly corrode at all – aluminium and copper, for example. Yet we go on using iron and steel more than any other metals. Why?
- Suppose someone invented a cheap, easy-to-use method which stopped rusting for good. Obviously it would have many advantages. Can you think of any *disadvantages* there might be?

Car exhaust systems are badly affected by rust. An exhaust system made from ordinary steel costs £80 for a particular car. It lasts about 2 years before it has to be replaced due to rust. It is also possible to buy a stainless steel exhaust system for the same car. This is much less affected by rust, and lasts over 6 years. The stainless steel system costs £155.

- Which is cheaper in the long run: the ordinary steel system or the stainless steel one? Explain your answer.
- Less than 10% of car-owners buy stainless-steel exhausts. Comment on this fact.