Rusting

Class discussion (teacher-led) from a PowerPoint® presentation: CDROM index 07CD
There is no student worksheet for this activity.

Discussion of answers: CDROM index 07DA
This material is also provided on the CDROM as both a PowerPoint® presentation 07PP
and a teacher-editable Word® document 07WD – please refer to the Use section overleaf.

Technician’s notes: CDROM index 07TN

Topics
Rusting, corrosion and sacrificial protection.

Level
Able students aged 11–13.

Prior knowledge
Rusting of iron requires oxygen and water. Salt speeds up rusting. The sacrificial protection
of iron by more reactive metals, such as zinc or magnesium.

Rationale
This activity looks at rusting in the context of shipwrecks. It aims to develop higher order
thinking skills including some lateral thinking and creative thinking. It has different
demands to the traditional experiment to show the factors needed for rusting to occur.
**Use**

It is best used as a teacher-led class discussion using the PowerPoint® presentation (07CD), leading to group and practical work. The first parts could be used as an episode to follow on from an introduction to rusting or for students who already know which factors are required for rusting. The planning exercise at the end is optional and the activity can be used without it.

It starts with a lateral thinking exercise. The students may not have met these before and you might want to go through an example with them – ‘Anthony and Cleopatra lie dead on the floor (in a pool of water)’. The students ask questions and in the end discover that Anthony and Cleopatra are goldfish whose bowl has fallen on the floor when the shelf, on which it was sitting, broke.

In the lateral thinking exercise in the activity the shipwreck in deeper water was carrying a cargo of zinc and magnesium. Gifted students could be asked to devise their own lateral thinking problems, perhaps for homework.

The students are asked to design a concept cartoon on the predictions about the shipwrecks. This can be done all together or in groups. It should have a drawing in the middle showing the shipwrecks at different depths and four speech bubbles around it expressing opinions about why one will be rustier than another. The best cartoons will be those with the greatest number of plausible explanations. Good examples of concept cartoons to show the students can be found in *Concept cartoons in science education*¹ or from other activities in this publication such as *Candle investigation*. A good idea might be to do a group effort on a different topic on the board before the students produce their own. One example could be four opinions on: whether mayonnaise is a liquid or a solid; whether magnesium would dissolve in acid on a space station; what climate change will mean for the UK; who is doing the greater good for humanity, the doctor or the research scientist working on a cure for cancer.

If you want the students to carry out their planned investigations it will need some preparation in advance. A suggested list of some apparatus required is included for technicians.

The students may find getting reliable results difficult and should be encouraged to run double experiments so that they get an idea of the reliability. A couple of methods they could try for measuring the amount of rusting are weighing the dried rust after filtering or weighing the nails and recording mass lost as rust.

The *Discussion of answers* is also given in Word® (07WD) and PowerPoint® (07PP) formats to suit the teacher’s requirements. Selected slides from the *Discussion of answers* sheet could be incorporated in the main PowerPoint® presentation (07CD) to avoid jumping from one to the other.

Lateral thinking problems

• A problem is given to which the answer is not straightforward
• You need to ask questions (that can be answered yes or no) to find the solution to the problem
• For example – Anthony and Cleopatra lie dead on the floor...
There are two shipwrecks. One in deep water and the other in shallow water. The one in deeper water is less rusty. Why?

Ask your teacher questions that can be answered yes or no to uncover the answer.
Some lateral thinking solutions you may have thought of

• The deep shipwreck was made of wood/aluminium/better painted etc
• The deep shipwreck was in fresh water and the shallow shipwreck in salt water
• The deep shipwreck was carrying a cargo of zinc or magnesium metal
• The shipwrecks have been there for different lengths of time
• Divers visit the shallow shipwreck and add oxygen to the water
• Fish excretion changes the pH of seawater

You may have thought of many others, if so well done.
Now let’s consider a fair test

Now let us consider what explanations could work if this was a ‘fair test’ - *ie* the ships are identical and the only factors about the seawater that change are those that depend on depth.

A fair test:

- Two identical ships with identical cargoes are sunk in seawater
- One sinks in shallow water and the other in deep water

Design a concept cartoon with four predictions with reasons for which shipwreck rusts faster.
Some hints for reasons for predictions in concept cartoon

- The shallow seawater is warmer
- The shallow seawater has more oxygen dissolved in it
- The shallow seawater is moving with a faster current or is stirred about more
- The concentration of salt in solution varies with depth
The best explanations take the reasoning further and explain why...

...the shallow water might be warmer?
...the shallow water might have more oxygen in it?
...the shallow water might get stirred up more?
...the shallow water might have a higher salt concentration?
Choose the prediction and explanation that you think are most likely.

Rust
Applications in real life

Who might be very interested in how the rate of rusting changes with depth at sea?
Planning

• Plan an investigation to determine how temperature, the salt concentration, the dissolved oxygen concentration or the amount of stirring affect the rate of rusting of iron shipwrecks.
Hints

• Real shipwrecks are unlikely to be available, so you will need to *model* the complex situation with something more simple... a nail perhaps?

• You need to consider how you will measure the amount of rusting.

• Rusting takes a long time. Your experiment needs to run for at least a week, perhaps longer.
The solution to the first problem is that the ship in the deep water was carrying a cargo of zinc and magnesium. These two metals are both more reactive than iron and will protect the iron from rusting by sacrificial protection (they corrode first).

They need to be in direct contact with the iron so electricity can flow from one to the other. When the ship sank the cargo was thrown against the hull of the ship which scraped off the paint and left the zinc and magnesium in contact with the iron hull of the ship.
The shipwreck in shallow water rusts faster because there is more oxygen in the water close to the surface.

The shipwreck in shallow water rusts faster because there is more salt in the water close to the surface.

The shipwreck in shallow water rusts faster because the sea is warmer close to the surface, which gets the sunlight.

The shipwreck in deep water rusts faster because there is more oxygen in the water. The fish that live mainly near the surface remove dissolved oxygen from the water as they breathe but there are fewer fish in deep water.
Further thinking

...the shallow water might be warmer because:
• water above 4 °C expands on heating and so rises upwards through colder, denser water. The sun heats the surface of the water. Less sunlight gets down to the deeper water which is therefore warmed less.

...the shallow water might have more oxygen in it because:
• the shallow water is closer to the surface and therefore nearer the source of oxygen (assuming it is dissolving from the air).
• more sunlight will reach the shallower water, encouraging more photosynthesis and therefore more production of oxygen.
Further thinking

...the shallow water might get stirred up more because:
• the water nearer the surface is likely to be disturbed more by the waves.
• more sealife occupies shallow water and will stir the water more.

...the shallow water might have a higher concentration of salt because:
• evaporation at the surface might produce a higher salt concentration as might freezing of seawater (when seawater freezes it leaves a proportion of its salt in the surrounding water). However, water which has a greater salt concentration may be denser than water with less salt and so may tend to sink to deeper water.
Choose the prediction and explanation that you think are most likely.

It is commonly the case that there are several competing theories and predictions about a problem. Often the best solution is to carry out some investigative work to test the theories.

This is the case with the shipwreck problem.
Applications in real life

Who might be very interested in how the rate of rusting changes with depth at sea?

- Salvage companies who may want to predict the extent of corrosion in sunken ships.
- Ship owners who want to predict the working life of their vessels.
- Oil rig companies who want the iron legs of the rigs to remain strong enough to support the rig.
- Naval historians who want to date artefacts or shipwrecks.
Planning

The details of each plan will vary but some general points to consider might be:

• The mass balance has a limited precision. It probably gives readings to the nearest 0.1 g or 0.01 g. Therefore data will be unreliable if you are measuring too small a difference in mass, so if there is only a small amount of rust, a mass balance will not measure it accurately.

• To obtain more rust you might consider using more than one nail and leaving them for quite a while to rust.

• You need to do the same experiment more than once to find out how reliable the data are. If the data from the repeat experiment are very different from the other data then your experiment is unreliable.
Rusting

If the class is going to carry out its plans it is a good idea to make it clear to the teacher which pieces of glassware you are happy to leave nails in to rust.

The actual requirements depend on the plan.

**Apparatus**
- Test-tubes
- Thermometers
- An electronic balance
- Water pumps
- Apparatus to draw air though the mixture in a boiling tube
- A kettle

**Materials**
- Nails
- Salt
- Distilled water
- Cooking oil
- Emery paper
- Filter paper

There is advice about rust stain removal in *CLEAPSS Bulletins 103 and 108.*
Chemistry for the gifted and talented

Rusting

Lateral thinking

The solution to the first lateral thinking problem is that the ship in the deep water was carrying a cargo of zinc and magnesium. These two metals are both more reactive than iron and will protect the iron from rusting by sacrificial protection (they corrode first). They need to be in direct contact with the iron so electricity can flow from one to the other. When the ship sank the cargo was thrown against the hull of the ship which scrapped off the paint and left the zinc and magnesium in contact with the iron hull of the ship.

An example concept cartoon

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Further thinking
Here are some suggested answers, but you may have thought of other and better ones.

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