Shipwrecks: a lateral thinking problem

This resource accompanies the article **Raising expectations** in *Education in Chemistry* which can be viewed at: https://rsc.li/3BmydTJ

Learning objectives

1 Develop higher order thinking skills including lateral thinking and creative thinking.

2 Design a valid investigation which models one of the factors that might affect the rate of rusting at different depths below sea level.

Introduction

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.

Prior knowledge

Learners will need to be familiar with the topic of rusting in order to be able to ask probing questions and design an appropriate experiment. Learners will need to be confident with the following scientific ideas:

- 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.

The questions on slide 8 help to assess and activate this prior knowledge and free up working memory so that learners can utilise the higher order thinking skills.

Teacher notes

This resource is best used as a teacher-led class discussion using the accompanying Powerpoint presentation, available to download from the Royal Society of Chemistry. The discussion will lead on to group and practical work. The lateral thinking section could be used as a lesson to follow on from an introduction to rusting of iron for students who already know which factors are required for rusting. The experiment design section is optional and the activity can be used without it.

Part 1: Lateral thinking exercise

The learners 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 learners ask questions which require a yes or no answer. Answer the questions to help your learners 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 this activity the shipwreck in deeper water was carrying a cargo of zinc and magnesium. You could ask gifted learners to devise their own lateral thinking problems, perhaps for homework.

Ask your learners to design a concept cartoon on the predictions about the shipwrecks. They can do this all together or in groups. The cartoon 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 support sheet contains templates for learners who do not want to draw the central image. The best cartoons will be those with the greatest number of plausible explanations. An example of a good concept cartoon is given on slide 11. It might be a good idea 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.

Part 2: Planning an investigation

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

Learners may find it difficult to get reliable results 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 the mass lost as rust.

Practical notes

The actual requirements will depend on the plans written by the learners.

If the class are going to carry out their plans it is a good idea to ask your science technician, if you have one, which pieces of glassware they are happy to leave nails in to rust. There is advice about rust stain removal in CLEAPPS Bulletins 103 and 108.

The practical may need to be left for some time (a week or more) so you will need to check with the technician or other teachers in your department which equipment will need to be returned if it needs to be used again during that time. Agree a suitable place where the experiment can be stored between lessons to prevent it being cleared away prematurely or tampered with in a way that might affect the results.

Apparatus

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

Materials

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

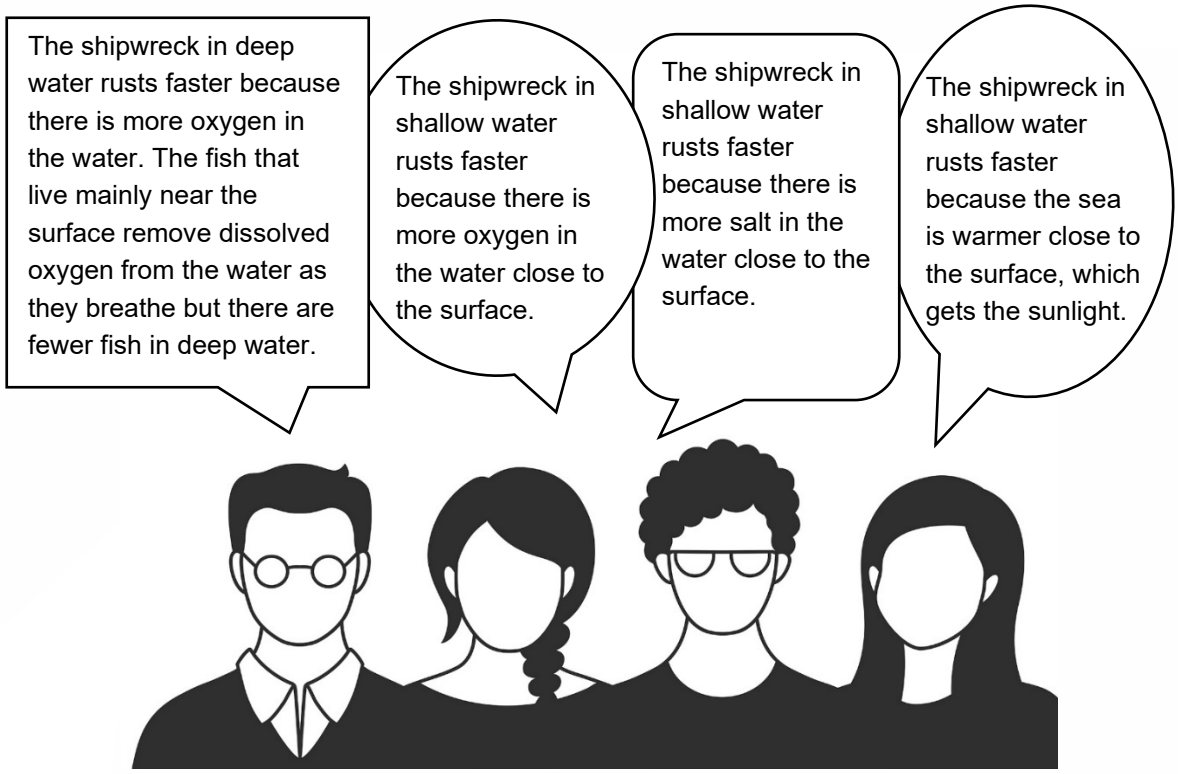
Discussion of answers

If you decide to run the lateral thinking problem as a game of 'twenty questions' (see the notes on slide 7) then a possible solution to the 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 that 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.

You can adapt the 'answer' to the ability of the learners in the classroom as this is a fictional scenario. Be guided by their prior knowledge to ensure that they will be able to ask the probing questions needed to reach the fictional answer.

An example concept cartoon



Further thinking

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

The best explanations take the reasoning further and explain why…

…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.

…the shallow water might get stirred up more because:

- the water nearer the surface is likely to be disturbed more by the waves.
- more sea life 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).

…the shallow water might have a lower concentration of salt because:

- water which has a greater salt concentration may be denser than water with less salt and so may tend to sink to deeper water.

Applications in real life

Who might be 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 artifacts or shipwrecks.

Planning

The details of each plan will vary but here are some general points to consider:

- The mass balance has a limited precision. It probably gives readings to the nearest 0.1 g or 0.01 g, so data are unreliable if you are measuring too small a difference in mass. Therefore, 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 is. If the data from the repeat experiments are very different from the other data, then your experiment is unreliable.