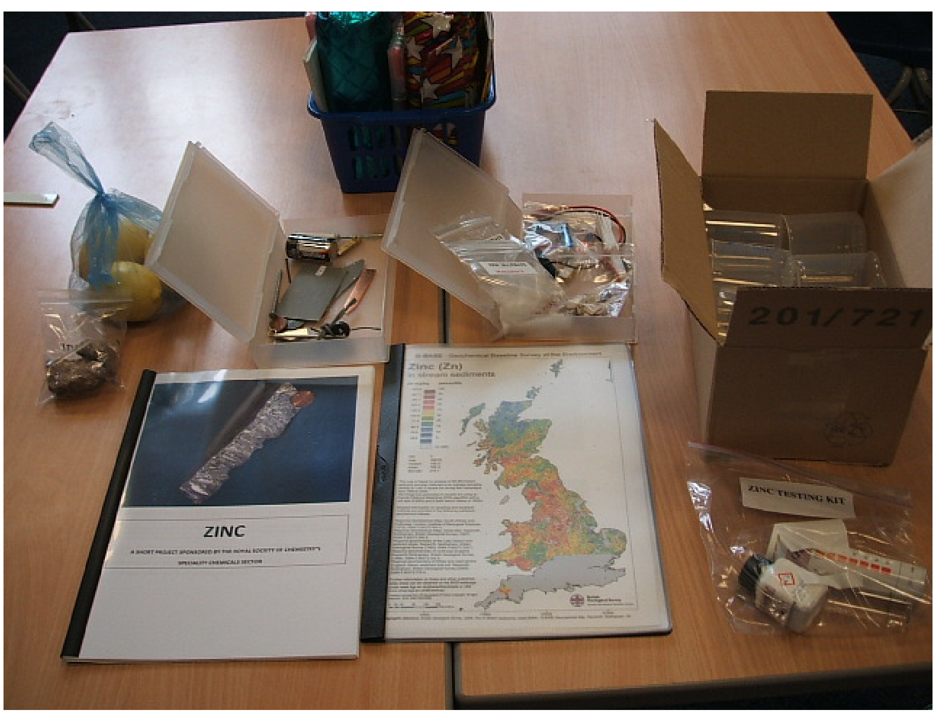
ZINC – A short Science Project for Primary Schools

Royal Society of Chemistry – Speciality Chemicals Sector



The Zinc Project

Project summary and suggested tasks.

1) Visit by the presenter – a half day overview with demonstrations and class work on science

2) Read the zinc notes to get a background on zinc.

3) Pick out some parts of the zinc notes to discuss with the class and discuss how they might set up the zinc plate drip experiment (Exp 1). Class sets up the zinc drip plate experiment with acidified tap water.

4) The class is asked to collect 5 soil samples to bring in for testing and asked to try and collect 5 samples of dirt and soil where zinc may have accumulated from dripping off galvanised fences or similar.

5) Testing of soil and dirt samples and the zinc drip plate water.

6) Class is asked to hunt for metals that may be zinc at home and rub a small piece of sandpaper on the item and bag the sandpaper. Each sample should have a written description of what it was rubbed on. Warn them not to rub important objects or damage shiny surfaces.

7) Test sandpaper rubbings.

8) The class tests a small sample of zinc ore (sphalerite), (exp. 2) by grinding up using a ball bearing on a hard surface.

9) Class sets up the lemon experiment (exp. 3) and leaves it running for one day.

10) Class tests the lemon experiment for zinc. Teacher only uses knife to slice up lemons. Class sets up the zinc plating experiment (Exp 4) and observes at ½ , 1 and 24 hours later.

Teacher disposes of all zinc chemicals and test solutions by washing down the sink. The sphalerite(zinc ore) despite being relatively safe should not be left as a class exhibit, it can be thrown away or kept somewhere safe for future use.

All the little pieces of materials, battery holder, wires and the 12 measuring beakers can be kept by your school.

11) Send the results to Steve Conway. email: grace@csteve.fsbusiness.co.uk

12) I'll collate the six schools results and send you a copy back.

ZINC

Sponsored by Royal Society of Chemistry's Speciality Chemicals Sector

Teachers' notes

'Zinc' is a short chemistry project for years 5 & 6 but can be used for larger age range groups too. These notes are to be used as a detailed background for teachers to understand the science and technology of the presentation and subsequent class work. The figures and photographs referred to within the notes are separate to enable their use with the class.

A short history.

North Wales has always been a place to mine for metals. The earliest use of metals is obscure in Wales but from other parts of the world there is evidence of people using iron from meteorites and natural copper metal, though both are rare. Natural copper has been found in several Welsh mines and it is likely it was used alongside stone tools. By 3000 years ago copper, found as the natural metal, is likely to have run out and people began mining copper ores. An ore is a substance containing the metal but it is locked up; chemically bound to another element, often oxygen, sulphur or both carbon and oxygen, as in carbonate. Copper ores come in several distinct chemical types. Some are easy to turn into metallic copper and those were sought after early on, while the more difficult copper ores were thrown away. Later still, when knowledge improved, the difficult copper ores were mined and turned into copper. This became known as the Bronze Age when tin from Cornwall was added to copper to make the harder mixed metal known as bronze.

The Iron Age followed and by Roman times several new metals were in use, particularly lead. Lead always contains a little silver and the Romans found a way to extract the silver and use the lead in many ways, including accidentally poisoning themselves with it. They would have been familiar with lead deposits in North Wales where it follows a curved band of limestone from Prestatyn, near the coast, through Halkyn to Minera, near Wrexham. Roman bars of cast lead stamped in Latin, with possibly the name of the local tribe, Decangli, have been found in Flintshire.

A long period of low technology life followed the break-up of the Roman Empire in Britain but gradually lost skills and knowledge were rediscovered. About 500 years ago mining began again on a scale comparable to the Romans when Welsh miners, sometimes helped by German miners, exploited the lead deposits. An influx of Derbyshire lead miners, whose surnames still survive today in the local population, helped to increase production further until the production of lead ore peaked in mid-Victorian times. The ore had become progressively harder to extract at depth due to water, despite the amazing 10-mile long Milwr deep drainage tunnel drying out large areas from Bagillt to Cadole, near Loggerheads. To drain and run a deep mine can be very costly, even today with modern machinery. Such was the hunger for metals the whole area has been riddled with more than 60 miles of tunnels often intersecting natural caves making it the biggest system in Britain.

Three hundred years ago a typical miner in this arc of limestone would find the deposit at the surface and dig down following the ore. There were small pits and much deeper shafts, all adding up to hundreds of mines along the arc from Prestatyn to Minera. Areas of Minera and Halkyn resemble land that has been bombed due to the large number of craters and bumps. Lead ore, called galena, is heavy and grey/blue when weathered but has a metallic sheen when fresh. It can't be mistaken and with hand tools the miners followed the veins, some as wide as two metres of solid lead ore. Other minerals, often in layers, including white calcite and a darker ore with a reddish/orange metallic glint, always accompanied it. This reddish ore was sphalerite, the main ore of zinc. These early miners couldn't use the sphalerite zinc ore for any purpose and consequently piled it up underground or they threw it away in spoil heaps at the surface.

What they were after was a less common white, or sometimes canary yellow zinc ore, called smithsonite. At the time it was known as calamine by them but this name has been dropped in modern usage to avoid confusion. They were also unable to extract zinc directly from this smithsonite ore but knew that when it was crushed and heated with copper and charcoal, it produced the very useful mixed metal or alloy, called brass. This process was again knowledge rediscovered, as the Romans were familiar with making brass by this method.

Brassworks appeared in Tintern, South Wales very early on and later across the river Severn in Bristol by the early 1700s. In North Wales a revival in fortunes for zinc came about from a process to make the metal itself in fairly pure form. Although zinc had been produced in India hundreds of years before, the process details did not pass westward and were reinvented in the 1740s. The zinc ore, sphalerite, once considered worthless was now extracted from the spoil heaps and collected from underground dumps too. Within a few years this collected and spoil heap material gave out and they once again mined sphalerite at depth. It was deep mined zinc ore that kept the Minera mines going, despite falling revenues from lead ore.

The new process to make pure zinc allowed a much better range of brasses to be manufactured and several firms came to the Greenfield Valley where waterpower was readily available. They made zinc and brass. Zinc producers also sprang up near Mostyn and at Dee Bank. A new process of using electricity to cover metal objects with a protective layer of zinc, galvanising, invented in mid-Victorian times caused another surge in demand for zinc. The early producers of zinc and lead often used crude methods to contain waste products and managed to pollute the environment so severely that today it would astound us. The landscape, now green, was often brown or completely denuded of plants. Toxic lead and very acid rain from sulphur dioxide gas coming from the treatment of lead and zinc ores caused significant local damage. Areas from Halkyn to the coast at Bagillt were badly affected at different times, depending on the intensity of lead and zinc ore extraction.

Chemists slowly improved the ore treatment processes and found ways to collect the acid gas and sell it as a product, sulphuric acid. Gradually the environment recovered but by the early 1900s most of the zinc ore had run out or was too expensive to mine. Cheap imports from larger mines abroad kept some zinc producers at Avonmouth, near Bristol, going until 2003.

Over a century from around 1850 to 1950 Flintshire and Denbighshire produced the largest share of zinc ore in the UK, with about one third of a million tonnes produced. About 150 000 tonnes of zinc metal would have been extracted from this ore from a century of mining effort in the two counties. This can be visualised as about 40 tennis courts filled to head height with zinc. By comparison this same amount of zinc metal that took a century to produce in North Wales is now extracted every five days worldwide in 2012. Despite having reserves the UK produces no zinc ore but it recovers some by recycling and imports the rest. Only three European countries are significant zinc ore producers, Ireland, Sweden and Poland.

Advanced note: Calamine was used as a name for two ores of zinc and from those zinc oxide was made and turned into calamine creams, used for a soothing and antiseptic lotion for inflamed skin. As the word ended up describing three separate materials it has been dropped as a mineral name, although is still used in the high street chemists for the lotion.

Key words:

Ore- A chemical substance containing a useful metal.

Galena- The main ore of lead- toxic, heavy, metallic looking.

Sphalerite- The main ore of zinc. Low toxicity. Often orange to red. Slightly metallic sheen if black.

Brass- A mixture(alloy) of copper and zinc.

Zinc- A metal of similar weight to iron but much weaker. Very bright when new but turns dull grey.

Galvanising- A way to coat iron and steel with a thin layer of metallic zinc to stop rusting.

Zinc and the human body

We're all familiar with the knowledge that a lack of iron in our body can cause noticeable symptoms, often beginning with tiredness. The very colour of blood is caused by iron as if to remind us of its importance and doctors use this sign as a quick check to assess levels. Zinc gets almost no mention of its role in the body but it is arguably more important than iron. A huge number of chemical processes within our body, our biochemistry, rely on zinc to work properly.

Our bodies extract zinc from our food and normally collect enough for our needs. Unfortunately, in many parts of the world foods are grown on soils deficient in zinc where even the food plants, that also need zinc to grow, struggle to thrive. Red meat is an excellent source of zinc but even livestock need to get their zinc from plants. These zinc deficient foods cause subtle changes in humans that are often difficult to pin down but can make them more susceptible to disease and they fail to grow and thrive as healthy adults. Britain has good levels of zinc in the soils that transfers to our meat and vegetables. In parts of Turkey the problem of zinc deficient soils was discovered quite late but zinc was added to fertiliser with dramatic effects on crops and improved health for the population.

As with most things, too much of a good thing can be bad for you. Our body only contains about two grams of zinc, an amount about the size of two peas. Swallowing two grams of zinc would make most of us vomit, feel very sick and produce a fever. It is not wise to drink from zinc-coated containers or tanks when they are small or have water that has stood in them for a while.

Zinc as a coating

Galvanising is the coating of zinc onto other metals, mostly on iron/steel but sometimes on aluminium. Iron is the world's most commonly used metal but it has a great disadvantage, it rusts. Oxygen and water get together to turn iron into a red oxide that ruins its strength. Fail to maintain a steel bridge and it will be weakened by rust and finally collapse. Salt from the sea spray or winter road gritting speed up rusting enormously. Coating iron with copper, nickel or shiny chromium stops rust by acting as barrier but small pits or scratches in the coating lead to deep pits of rust.

Zinc has a different action to copper, nickel or chromium when used as a coating. It will be attacked before the iron and even if scratched away the surrounding zinc still protects the iron from severe rusting until finally most of the zinc coating decays away. The process can be clearly seen on corrugated iron roofing sheets, commonly called tin roofs although they have no tin on them. When new they are very reflective with their zinc coating but within a year or two they are dull grey. Depending on the quality of the zinc coating, mainly its thickness, the corrugated roof sheet may last from 10 to 30 years before rust begins to appear as reddish patches amongst the remaining thin grey zinc.

There are two ways of coating zinc onto iron. The oldest method, developed by the French in the 1740s is simply to use an acid on the steel to clean it and then dip it in molten zinc. Today we have baths containing more than a 100 tonnes of molten zinc to dip large objects, as in beams, steel doors, gates and even lampposts. This gives the thickest coatings. A second way that took a century to develop and improve finally came into common use in the 1930s. This used electricity and a cold solution of zinc salts to plate a very thin layer of zinc on iron or steel. It is often used on cars today before they are painted so that a manufacturer can guarantee a rust free period.

Advanced note: Two different metals when touching or coated on another make a simple battery if wetted. Salt allows the electrical current to flow more strongly and cause more rapid corrosion. As a simple class experiment pairs of metals can be left in salty water – held together with a tight elastic band and as a control another set separated but still in the same dish of salty water. Copper and iron make a suitable pair.

The zinc crystal and spangles

Most of us have an image in our mind when we hear the word 'crystal'. It is often transparent, sharp edged and sparkling. Most materials will form crystals, glass being a common exception, but metal crystals are usually so small as to be invisible to us by eye. When zinc is coated onto steel from a molten zinc bath it forms flat, shiny crystals of metal that can be as wide as your hand or as small as a pinhead. The larger ones can be seen on coated metal items, as in lamp posts, sign posts, gates, covers, buckets and doors. The effect is unmistakable and is often called spangling. See photo 14.

Zinc as a chemical

Children and many adults are not sure of the difference between a metal and its chemicals. For example, it's often stated we need calcium for strong bones, yet calcium is a very light shiny metal that fizzes with violence if thrown into water. Eating a spoonful of calcium would probably be fatal. What our bones need is the calcium ion to make the hard mineral part. It is similar with zinc. We need the zinc ion, not the metal, to use in our bodies to make many of our proteins function.

Zinc metal dissolves in acids easily. In fact, sulphuric acid and zinc was once used to create hydrogen for manned balloons in the 1700s. The pool of clear liquid left over after a balloon launch contained the zinc ion and the sulphate ion, though in the real life situation the liquid is smelly and grey due to impurities. However, with pure zinc in the lab the liquid is water clear and contains the zinc ion. Zinc atoms in the metal are crowded together and interact with light so strongly that they reflect most of it back creating the shiny metallic effect. To become an ion, in their case, they need to lose tiny charged particles called electrons. Once each zinc atom has had two electrons pulled off by the sulphuric acid in water they become zinc ions and slip away like ghosts amongst the water molecules, being completely invisible. See fig. 1 Not all ions are invisible, some like copper are blue or green when concentrated in water but they are never metallic looking.

As zinc is more stable in a state where it has lost two electrons we rarely find zinc metal in nature and by analogy zinc metal made by mankind will tend to decay away back to ions where it can. If kept away from all other materials, including air, it will stay as the metal forever.

Advanced note: Chemists call the zinc ion with two missing electrons Zn(II) or Zn^{2+}. The atom was balanced with equal numbers of positive and negative charges but on losing two negative electrons it becomes doubly positive. The acid contains hydrogen ions that can capture one electron each from zinc and join together to form H_2 or hydrogen gas.

For simplicity for this age group this work on zinc discusses only the metal and the zinc ions found in many zinc chemicals. A great deal of chemistry does not deal with ions and ionic bonds but a stronger bond known as covalent. Zinc chemicals with these bonds are also common and the zinc ore sphalerite is a good example where all the atoms of zinc and sulphur are joined in one large molecule by covalent bonds.

The calcium in bones and teeth is in a mineral called dahllite, a calcium hydroxyphosphate with carbonate.

Key words:

Metal- A state of a material where the atom or atoms have their full complement of electrons and they also reflect light strongly.

Ion- An atom that has lost or gained electrons. Metals usually like to lose them. Zinc is more stable losing two.

Electron- Tiny charged particles that surround the central part of the atom. In the process of being lost, gained or shared between atoms they create all the chemistry.

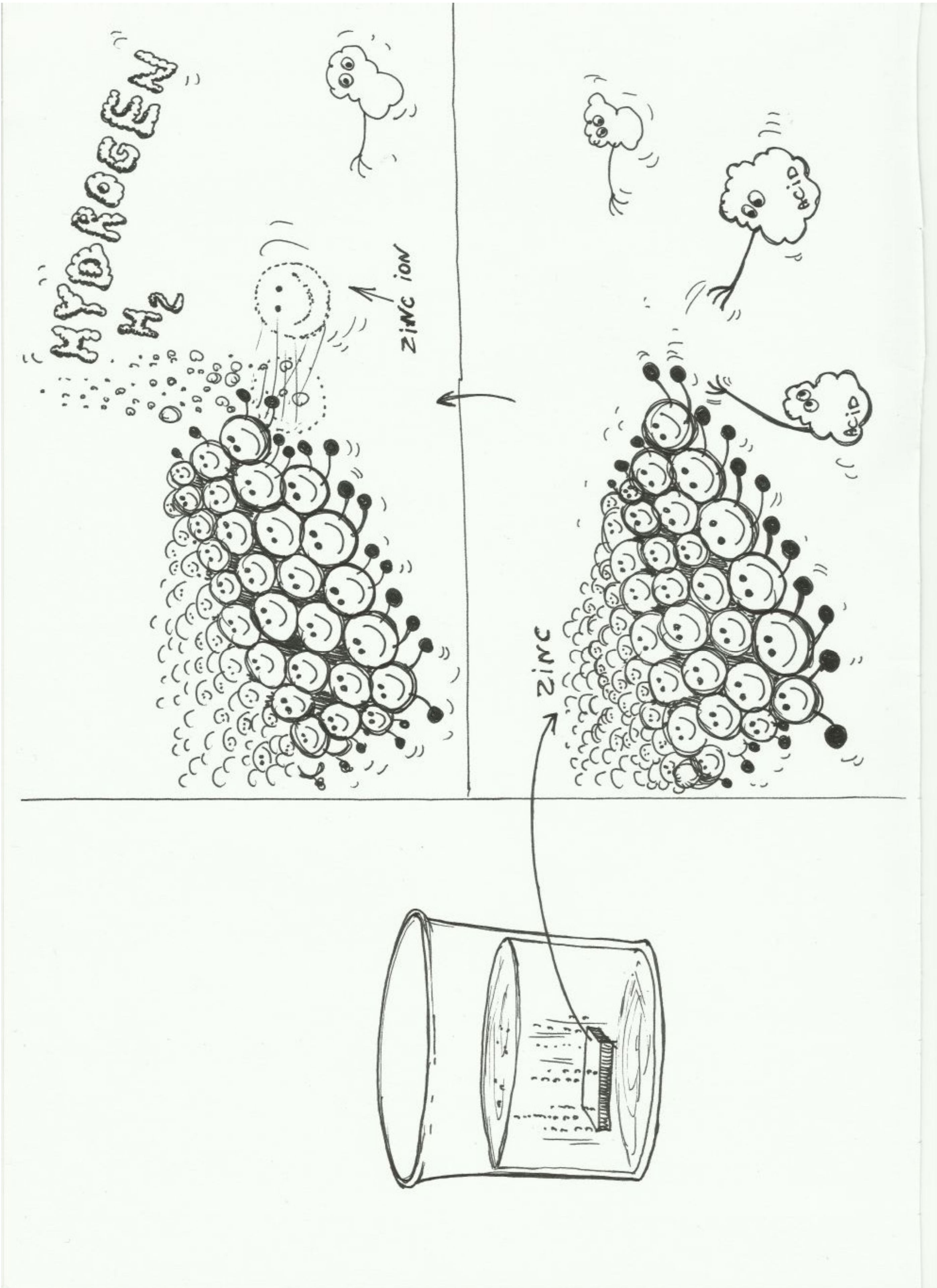


Figure 1

Weathering and zinc

Lead has traditionally been the choice for parts of church roofs but zinc is more versatile and safer. It is used for cladding and roofing and can be darkened with artificial treatment. Examples of zinc-clad buildings in our region include the Ruthin Craft Centre, Theatre Clwyd in Mold and the Colwyn Bay shopping centre.

Zinc metal left out in the rain to weather, very slowly disappears. The acid in the rain, natural and manmade, turns it into zinc ions that flow away invisibly. In large cities the rain is often more acid and zinc is thinned faster. In clean countryside air away from animal farms it will last for much longer. The colour changes from shiny metallic to whitish grey with time as oxygen and carbon dioxide dissolved in water attack the surface. The thin layer slows the loss of zinc but gradually it all dissolves away. Zinc cladding of two millimetres thick will last a lifetime or more but galvanised coatings can be very thin (in some cases deliberately thin) and corrode away quickly e.g. car exhausts.

Zinc ions in water dripping onto plants below will often kill plants if concentrated enough. See photo 17. In this photo zinc from railings along Colwyn Bay sea front have dripped zinc-laden water onto microscopic dark lichens growing on the concrete and killed them. Unfortunately, many dark flat tiny lichens are mistaken for dirt!

The common zinc batteries

Common batteries like the typical AA cell are made from zinc metal, either as a zinc cylinder containing the moist powdered chemicals or as zinc metal powder in the jelly-like chemicals. The zinc gives away two electrons to become a zinc ion and the electrons can be harnessed as a flow of electricity. The common zinc battery turns zinc into zinc ions and effectively gives out electricity. Of course when the zinc metal has all gone the battery is dead but the zinc ions are still inside the case. Until about 30 years ago the battery that used a zinc case was the only common battery and it used to leak as the case itself was eaten away. They're still around as the cheapest batteries. The more expensive 'alkaline' battery that uses zinc powder inside a steel case is now more popular as it leaks less and lasts longer.

Advanced note: The common batteries all use pairs of materials to generate their power but to avoid complications the other half of the battery contents, a black paste of manganese dioxide with added carbon, can be ignored for primary level. All batteries also need a fluid (an electrolyte) to allow the electricity to flow from the one part to the other. In the cheapest batteries this fluid is an ammonium chloride/zinc chloride solution and this is used to name the battery although it is technically incorrect as both zinc batteries on sale, 'alkaline' and 'zinc chloride' are zinc-manganese dioxide batteries.

Safety note: The cheapest batteries, if opened, contain chemicals that are messy rather than harmful but alkaline batteries contain a strong alkali that can damage the skin and produce red sore patches if the hands are contaminated.

Zinc die-casting

In every home there will be many zinc die-cast parts. The molten metal is forced into the mould or die and the machine then automatically opens and the part falls or is pushed out. The die closes and more metal is injected for the next identical part. It is a very large industry. Zinc is ideal as it melts at low temperature compared to iron or copper. Metal toy cars are nearly pure zinc. Small parts in washing machines and cars are often die cast zinc. Parts of window catches, door handles, door catches, vacuum cleaners and computer printers also frequently contain die-cast zinc parts. Its rival, aluminium is much lighter and stronger but is more difficult to cast.

Coins

A few countries have experimented with zinc for coins before 1950. Belgium had two low value coins minted while under German occupation in WWI. Austria and Germany tried them too. They have not fared well as they wear rapidly and become a dark grey colour. In the last 20-30 years the UK and the USA found that copper in low value coins was worth more than the coin, in the cent (US) and 1p and 2p (UK). These coins were altered from pure copper. The UK went for steel coins coated with copper but the US used zinc coins coated with copper. Swallowing ten UK 1p coins wouldn't cause much of an effect* while you waited until they popped out the other end but the US 1 cent coins would dissolve in our stomach acid and give you a large dose of excess zinc that will make you feel very ill. Dogs in the US swallowing coins have no problems unless they swallow a one cent coin, then they sometimes die from zinc poisoning.

The £1 and £2 coins of the UK are made of brass, the £1 coin entirely so. Brass being a copper-zinc alloy, a typical £1 is about one quarter zinc, the rest being copper with a little nickel.

* Obviously not an observation to be passed on to children, as there can be some effect from dissolving copper and iron in the stomach from UK coins in some individuals, besides the coins occasionally failing to come out.

Paint

During the processing of the ore a zinc chemical can be extracted without producing the metal. This white zinc oxide was recognised early on and when it was mixed with linseed oil it made a suitable white paint. However, it looked a bit 'thin' when used and was soon overtaken by whiter lead chemicals with disastrous results for small children chewing on paintwork or paint flakes in the home. Modern white paint uses safer, much whiter pigment, titanium dioxide. Zinc white, sometimes called Chinese white, lives on in artists' paints to produce a particular shade of white and is often still added to other paints to help protect iron from rust.

Fencing wire

Fencing wire in square sections of thick wire, called stock proof fence is very common in the country. In town a chain mesh of interlinked segments showing a diamond pattern is common for gardens and other boundaries. Chicken mesh is even thinner wire. All these fencing wires can be coated in zinc giving them a distinctive matt grey colour. Plastic coatings are also used but they give no protection to the iron wire inside if the coating is damaged. For fence wire coated in zinc, see photos 6 and 13. Britain probably holds the dubious record of having the most barbed wire in Europe, all of it zinc coated. Getting injured by zinc-coated barbed wire is more antiseptic than by rusty barbed wire.

Hidden zinc in soils and vehicle tyres

Have a look at the distribution of zinc across the UK on the separate map. In the far north of Scotland the rocks are very old and depleted in zinc, coloured blue. In much of Wales there is a mid-range coloured yellow and just visible close to the north coast is the arc of higher levels of zinc, coloured red, from Prestatyn to Wrexham. These measurements were made from thousands of stream sediments samples. Zinc is also higher in mountainous harder rocks of Wales and the Lake District. Zinc in soils is usually from the underlying rocks but it can also be from fertilisers and sewage added to soil.

Car tyres contain small amounts of zinc oxide as a processing aid for the rubber. When a car tyre wears the rubber left on the road releases the zinc, which usually ends up in soils and rivers. It doesn't seem to do any immediate harm but zinc can rise to unacceptably high levels in some sewage works from a combination of industrial waste, human waste and road drainage. At high levels, metal ions in sewage kills the bacteria and other microscopic creatures detoxifying and eating the waste in the filter beds of the works.

Identifying zinc coated materials

If a spangle effect is visible then it is zinc. If a fence wire is pale grey then it is also zinc. Safety fence (crash barrier) is grey from zinc but is often dark from road dirt or even slightly orange from underlying rust. The A55 road shows a series of examples from new to rusty. See photo 15. Buildings covered in zinc are usually a range of greys from light to dark and it is often used on vertical faces. Lead, the other common metal on roofs, usually weathers a whitish grey with white streaks in parts, it is rarely used in vertical sheets as it is very weak.

Grey letters on gravestones, often dropping out, are lead or later, 1960s, resin filled.

Grey paints are sometimes used with zinc metal mixed in and these are harder to pick out. They are more common on lamp posts. Grey plastic is common on road signs and posts but often shows up by peeling or cracking.

Roofing that is grey and corrugated is likely to be zinc coated and it was very common, particularly for farm buildings, when plastic was rare. See photo 3. It is still used but with high iron prices is less common. In many other countries painted steel roofs, without corrugations but with a zinc coating are very common. In one steel-making town in Poland a whole house made of steel, the roof, walls and floors still survives but it would have benefited greatly from a zinc coating.

Pylons (electricity towers) are often zinc coated when new but as they age they are repainted with grey paints containing powdered zinc. See photos 3 and 11.

Car exhausts, made of steel, best seen at the fitting centres are coated in a very thin layer of zinc just enough to make them last a few years.

Screws and nails are often zinc coated. They can be dark grey on nails or brightened as in many screws. Zinc coated nails are always used to hold on slates as they last much longer.

Shaped pieces of zinc, from finger-sized to hand-sized, can be seen in canal boat shops. These lumps are bolted on to the iron canal barges to reduce the rusting in places not easily reached. The Conwy tunnel's outer steel lining is protected by such pieces of zinc that decay away before the iron rusts badly, giving it a longer life.

Brass

There are many alloys of zinc with copper and these are usually called brass. Some coins have already been mentioned as using brass but it is now less commonly used for ornaments due to the high price of copper. Many houses had large numbers of small brass ornaments on shelves but the fashion for these died out by about the 1960s. Most have now been melted down for their copper content. Brass is still common as fittings in houses as handles, catches, door handles, window catches, water valves under the sink and even electrical fittings. They are distinctive in colour but plating brass onto plastics can cause confusion with solid brass, unless the object can be handled. Buttons were once made of brass and Birmingham had a huge trade in brass objects. Taps on sinks are often brass but as it tarnishes they have two layers on top, first nickel and then chromium.

Bullet and shell cases are mainly brass and large numbers are still made in the UK. WWI and WWII caused a huge upsurge in the need for zinc to make brass shell and bullet cases. As they are ejected and scatter around the gun that fires, many brass cases can be collected and reused or recycled.

Zinc's relatives

Zinc has two chemical-relative metals, cadmium and mercury. In many cases, particularly in earlier times industry jumped ahead of chemistry and simply tried something new without considering the chemical consequences. In other cases chemists developed a process and from inadequate knowledge at the time a later hazard had to be removed by the work of another group of chemists. Mercury was known to be a toxic metal for many years before laws were bought in to curb its uses. In zinc batteries it was added to improve performance but used batteries ended up in landfill and incinerators releasing their mercury. It was the chemist's role to find ways to make the common zinc battery work as well without mercury and now most are mercury free thanks to a concerted effort by industrial chemists.

Cadmium is so good at protecting iron against rust, when applied as a coating like zinc, that it would have overtaken zinc in usage. Luckily, it wasn't as common to find deposits to mine and this kept the price higher. If it was as plentiful as zinc and was mined as zinc was in Flintshire much of the county would now have poisoned soil and water. The Japanese people found to their cost that cadmium is toxic when it killed more than 200 and injured many more, until about 50 years ago when it was controlled. Mines allowed cadmium contaminated mining waste to escape into the river water that was used to irrigate rice fields. The rice picked up high levels of cadmium. For years the people complained of 'ouch-ouch', or in Japanese 'itai-itai', disease, as it was so painful. Work on some of the last fields to be decontaminated of cadmium continues even now.

Cadmium coatings are still used but rarely now for items that would appear in the home. It was common on screwdrivers and even door hinges but is now only found where it is difficult to replace or does not come into contact with the public, e.g. aircraft parts outside the passenger cabin. Cadmium coatings have a distinct look; it is bluer and stays more lustrous than zinc.

Experiment 1. The weathering of zinc by rain

Aim: To show that zinc very slowly dissolves in acid rain.

Background and methods:

We could set the zinc up outside and collect the drips from the rectangular piece of zinc but with vagaries of our weather we may not have any rain or it may rain too much. It also takes a long time and very sensitive tests to pick out the zinc. Instead challenge the class to think of a way of dripping lemon water onto the zinc plate so slowly that only a litre or less drips onto it in one day.

The water must drip onto it and stay as long as possible before dripping off into a collection container. The collected water can then be tested for zinc with the zinc test strips. Natural rain is slightly acid and with pollution is even more acid. The worst of the acid rain is fortunately over with coal-fired power stations being less common and having been cleaned up.

For our very acid rain cut a lemon in half and squeeze one half into a litre of tap water. This will be the very acid rain. Check the pH with the pH test papers to see how acid it is before use. The lower the pH the more acid.

Controls: A zinc test strip should be used to check the level of zinc in tap water alone. In any scientific experiment several measurements should be made but controls are very important too. We could make a hundred measurements after we have run the experiment and discover a certain level of zinc was dissolved by the drips but if the water from the tap already contained a lot of zinc it would make the experiment meaningless. We wouldn't expect a lemon to contain much zinc but tap water if stored in a loft tank coated in zinc (galvanised) would contain some.

Important: Before testing the lemon juice water we need to reduce the acidity. We do this by adding a little sodium bicarbonate and then checking that the pH is at 7 or above. Use the pH paper by tearing off a small piece, dip it in and compare the colour. Warning: Keep your hands, or the children's hands, clean of lemon juice water when testing for pH or you may ruin all the pH paper by contamination with acid lemon juice. Once the pH has been increased to 7 or more we carry out the test for zinc as normal. The plain tap water does not need to have its pH increased as it should not be acid and we can carry out the zinc test directly.

Neutral is pH 7. Acid is less than pH 7 and alkaline is pH greater than 7.

Supplied: One zinc plate- not to be confused with the zinc strips for the lemon experiment. The zinc plate can be bent to catch drips from your apparatus but wash hands afterwards to avoid contamination of any zinc tests.

Tests:

Tap water- use one pH strip of paper and compare the colour with the chart. Then use one zinc test strip.

Lemon water dripped onto zinc: Test pH before use. Make up to one litre again after catching drips by adding tap water, stir and test using one zinc test strip.

Experiment No. 2 Detecting zinc in zinc ore

How easily does zinc leach from the zinc ore, sphalerite?

Background and methods:

Sphalerite was known as ‘black jack’ to many miners, as sphalerite can contain so much iron it looks a metallic black. Pure, water clear, sphalerite is unknown in nature but pale yellow and reddish colours are common. The samples are yellowish-red sphalerite from mine dumps on Minera mountain near Wrexham.

In sphalerite the zinc is held strongly by sulphur. Sphalerite would be roasted to remove the sulphur and in the early days this would be lost into the air as sulphur dioxide, a choking gas. Mixing, the gas would join with more oxygen and finally fall as sulphuric acid in rain. This caused damage to crops, wild plants and even limestone buildings, wherever the process was carried out.

Remove some small bits of sphalerite, a few millimetres long, from the mineral sample. Take care to avoid any grey metallic lead ore that may be exposed by accident. Crush the small bits with the back of a teaspoon on a hard surface. Mix the powders together and then split into two samples.

Put both samples in separate beakers and add a teaspoon of warm water to one and a teaspoon of lemon juice to the other. Leave overnight.

Test the sphalerite and water sample directly but with the lemon juice sample add a little sodium bicarbonate to reduce the acidity until it stops fizzing. Then test as before for zinc.

We are looking to see if we can find any increase in zinc ions removed from sphalerite with acid, as would happen naturally on mine dumps. Of course, it doesn’t rain lemon juice but a mixture of natural acid rain and man-made acid rain is always present. Natural acid rain comes from carbon dioxide and most man-made acid rain presently comes from transport exhausts but even chicken farms can be a source. Many plants also produce a range of acids that they exude through their roots to help capture nutrients.

Experiment 3. The lemon experiment

The aim of the experiment is to follow the movement of zinc when set up as a simple battery. Also to understand that zinc is removed from the metal plate and becomes zinc ions in the lemon juice.

Background:

Early batteries were piles of copper and zinc disc separated by salt soaked cloth. Invented by Alessandro Volta in 1800 after discussion of his friend's experiment, His friend, Luigi Galvani had touched a frog's leg hanging from a brass hook with an iron scalpel and it twitched. He had accidentally made a simple battery that made the frog's muscle contract. The 'volt' and 'galvanising' come from their names.

Two lemons are used. In one we set up the experiment by inserting a zinc and copper sheet but **do not** connect them with a wire. This is the control experiment. In a second experiment we insert the zinc and copper sheet as before but this time we connect them together with a wire. This second experiment is acting as a simple battery with a small amount of electricity flowing through the wire.

The experiment will try to show that zinc is being used by the battery and ends up as zinc ions in the lemon flesh. How far the zinc ions will travel is unknown and that is why we are slicing and testing at several distances from the zinc plate. In the control the zinc will be attacked by lemon juice and some will get into the lemon flesh but we'd expect less than the one operating as a battery.

Children may ask why the lemon battery couldn't be connected to a bulb or LED to light up. The reason is a single set of zinc and copper plates produces only a very small voltage and not much power. Actual batteries are much more efficient. The lemon battery is sometimes sold as kit to power an LCD digital clock which requires very low power.

Method

Follow the instructions on the illustrated worksheet but see important note below.

Supplied: Two lemons, two zinc strips, two copper strips, wire with crocodile clips, beakers, sodium bicarbonate.

You supply- Sharp knife

Mark the beakers 1,2,3,4, 7 and 8. Call the results, Lemon 1,2,3,4,7 and 8.

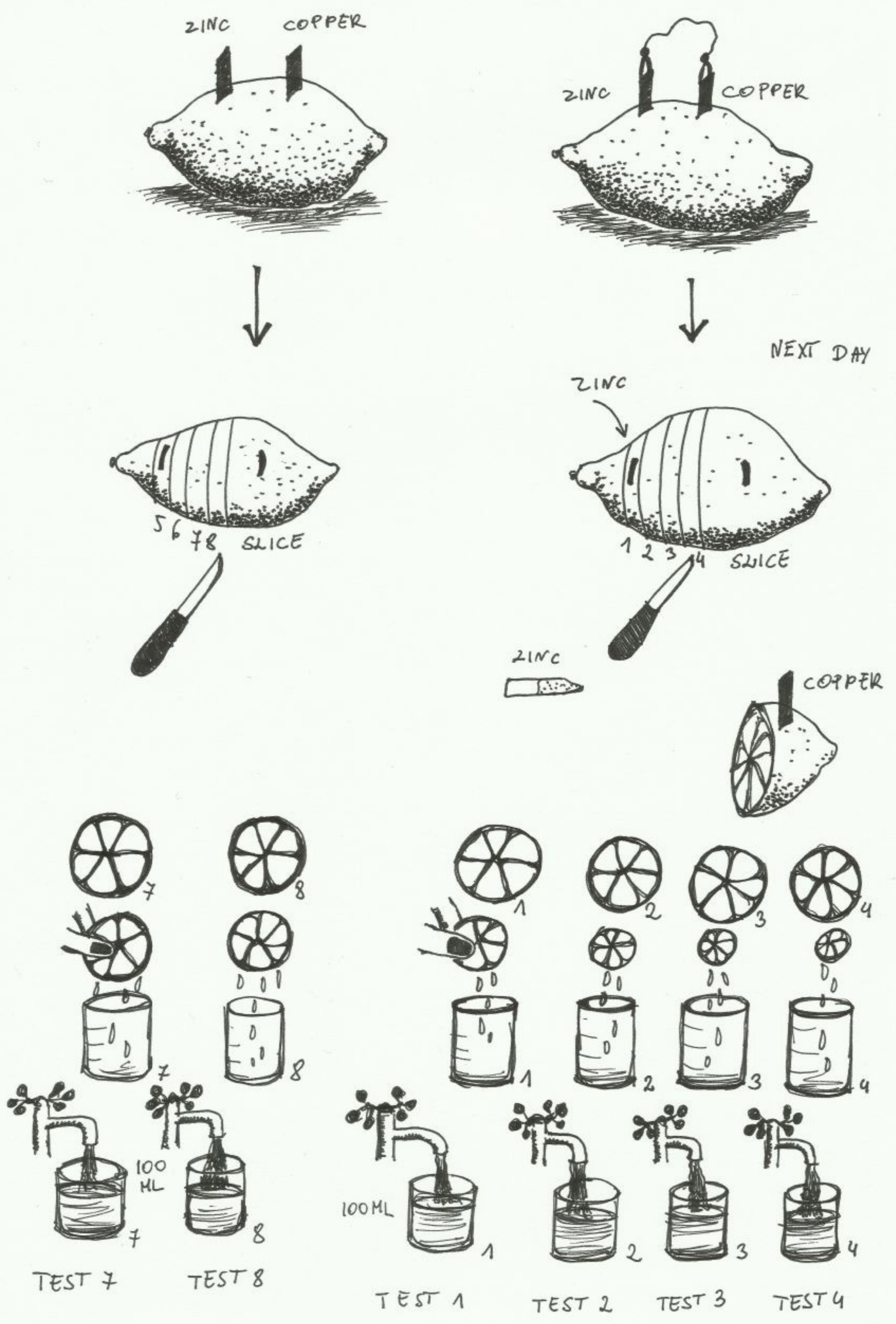
Contamination: Wash the knife after each cut- have a jug of water nearby. Keep the slices separate.

We're not testing slices 5 or 6 of the control as we're saving testing strips. They cost 60p per strip.

Note: Important, before testing the squeezed lemon juice from the slices we need to reduce the acidity. We do this by adding a little sodium bicarbonate and then checking that the pH is at 7 or above. Use the pH paper by tearing off a small piece, dip it in and compare the colour. Or if no fizzing occurs when adding a further pinch of sodium bicarbonate then it is not acid. Warning: Keep your hands, or the children's hands, clean of lemon juice when testing for pH or you may ruin all the pH paper by contamination with acid lemon juice. Once the pH has been increased to 7 or more we carry out the test for zinc as normal.

Neutral is pH 7. Acid is less than pH 7 and alkaline is pH greater than 7.

Safety: Children can squeeze the zinc contaminated lemon slices using fingers into six separate beakers but must be warned not to lick or suck fingers. Wash hands immediately afterwards and throw away squeezed slices immediately to avoid children eating one accidentally.


ZINC
COPPER
ZINC
COPPER
NEXT DAY
ZINC
5 6 7 8 SLICE
1 2 3 4 SLICE
ZINC
COPPER
7
8
1
2
3
4
100 ML
100ML
TEST 7
TEST 8
TEST 1
TEST 2
TEST 3
TEST 4

Experiment 4 The Plating experiment

The experiment shows how zinc ions can be forced back into zinc metal by the use of electricity,

Background

Most metals when found as ions in solutions can be forced back into metallic form using electrical energy. Some like sodium ions found when ordinary salt is added to water cannot be turned into the metal as the water breaks up first. Such metals can be recovered in water-free solutions or molten salts.

It was found early on that zinc could be plated onto a suitable metal as a thin layer. The simple method we will use will only allow the zinc to come out as a grey to black layer but it is still clearly zinc. More advanced plating baths using many more chemical additives can produce a bright metallic zinc layer.

The electricity supplies the electrons that the zinc ions have lost when they became ions. They need two each and that enables them to become the metal again. Electricity can not only be used to plate metallic layers on many surfaces but can also be used to clean up metal solutions that cause pollution.

Method

Dissolve the two grams of zinc sulphate into 50ml of water in the beaker. Set up the circuit as in the fig. 2 drawing. The connection of the leads in any particular way does not matter in the circuit, though for educational purposes the black lead should come from the negative side of the battery and the red lead from the positive side.

Make sure the copper electrodes dip well in to the solution and are not too far apart, say two centimetres. Hold them in position with a bit of tape. Fit the battery when all is set up.

Observe after a short time, then an hour and finally next day by which time the battery will be totally dead. The electrodes can be removed and patted dry on tissue to observe more closely.

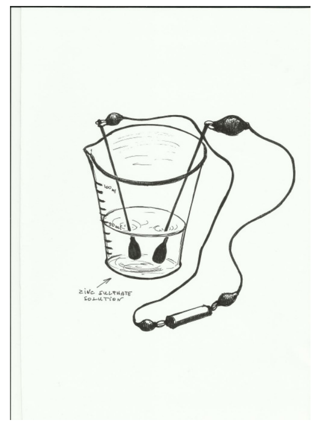


Figure 2

You may find copper and zinc have appeared by next day. The battery drives the zinc ions from the zinc solution back into metallic zinc but also on the other electrode it dissolves copper. These copper ions often cross over and coat the zinc after a longer period.

Get the children to observe which copper paddle-shaped electrode- the negative or the positive accumulated the zinc.

Safety:
The zinc solution is poisonous and is enough to make child who drinks the whole beaker quite ill. It is important that you keep the zinc sulphate chemical and its subsequent solution under supervision. Make sure that no child dips their fingers in this solution as it can damage children's eyes if rubbed in. It is an experiment to be carried out by you for the class to observe.
Dispose of the solution down the sink as soon as the experiment has finished. Flush with plenty of water. Keep away from ponds or fish tanks as zinc solutions are much more poisonous to small pond animals than they are to us. The little copper spade-shaped electrodes are safe even if coated with zinc.

Testing for zinc using the test strips

You have about 47 test strips, a small white plastic bottle of sodium hydroxide solution and a clear container marked 5ml.

Testing liquid samples:

Pour a little less than 5ml up to the mark in the clear container. Make sure these solutions have been changed from acid to neutral if they were lemon juice related.

Add 8 drops carefully from white sodium hydroxide solution.(Teacher only, due to danger of sodium hydroxide solution). It says 10 drops but with 8 you shouldn't run out.

Swirl to mix and then child can dip in the test strip. Pull out and compare with the colour chart after 30 seconds(no need to time it). The colours are quite close but you should always be able to say red for zinc and orange for little or no zinc. Make a note of the concentration if you can definitely make out the shade of orange.

Soil and dirt samples:

Put in a beaker and add water upto 100ml and one teaspoon of vinegar. Leave overnight. Pour out some liquid next day and add a little sodium bicarbonate until it stops fizzing. Then test as above for liquids.

Zinc hunting: sandpaper samples.

Drop the sandpaper rough side up into the test container and drip 8 drops of sodium hydroxide directly on it. Swirl it to wet it. Leave for a few minutes then add water up to the 5ml mark. Dip in the test strip, pull out and wait 30 seconds for the colour to develop and compare on the chart.

Always wash out the test strip container after each use.

Index of laminated photos of galvanised steel

1) **The sliding gate**: A typical steel security gate that needs to last a long time without rusting.

2) **A kiosk**: This kiosk is in Caernarfon and is now less common as many are now made of plastics. A kiosk could be made of cast iron, very heavy and thick, as are post boxes but this is thinner steel given a protective coat of zinc. It must resist road salt that splashes against it in winter.

3) **A pylon, corrugated roofing sheet and barbed wire:** All have been discussed in the main text.

4) **A field gate:** Many farm gates and temporary animal pens are made of zinc-coated steel. Paint can be rubbed or chewed off easily by animals allowing rust to set in. Zinc coatings are a cost effective alternative.

5) **Palisade fence:** From the word ‘palus’ meaning stake or boundary, the palisade fence is strong but would rust quickly. Each part is coated in molten zinc separately and then joined together.

6) **Fencing meshes**: These classic meshes are common but expensive. They would rust away within five years if left unprotected. The razor wire in coils at the top is heavily zinc coated to stay sharp.

7) **Stairway**: Typical of steelwork in outdoor industrial areas. The steel protected by zinc allows many years of safe access. The steps of a rusty stairway may suddenly give way. Also found on seafronts.

8) **Lamp post**: Steel lamp posts are cheap but very vulnerable to rusting from road salt. Zinc extends their life.

9) & 10) **Manhole covers**: Most street manhole covers are heavy cast iron. They rust slowly but are very thick. Covers elsewhere are thinner steel and need protecting by zinc.

11) **Pipes:** Pipes used for temporary connections can be steel coated with zinc.

12) **Water tank:** This is a rare steel reservoir, almost as large as an average primary school and coated in zinc.

13) **Chicken wire:** One of the common wire meshes**.** Without the zinc coating it would rust through within a year.

14) **Zinc crystals**: Each patch is a crystal as all the atoms line up. They grow outward until they meet their neighbours. Sometimes called ‘spangling’.

15) **Safety fence**: It comes in box shapes, ‘W’ shapes and wire. All are zinc-coated steel.

16) **Scaffolding tubes**: These tubes get rough treatment. Paint or plastic would scratch off allowing rust underneath. Such rusty scaffold would be dangerous. Zinc coating allows visible protection while putting upwith scratches and inhibiting rust.

17) **Lichens:** Many lichens are sensitive to pollution. These are killed by zinc leached from the steel railings.

18) **Steel roof wire**: A shelter on the shores of Llyn Trawsfynedd has the roof held by steel wire and zinc coated tension ties. The ties have lasted well but the wire is badly rusted.