



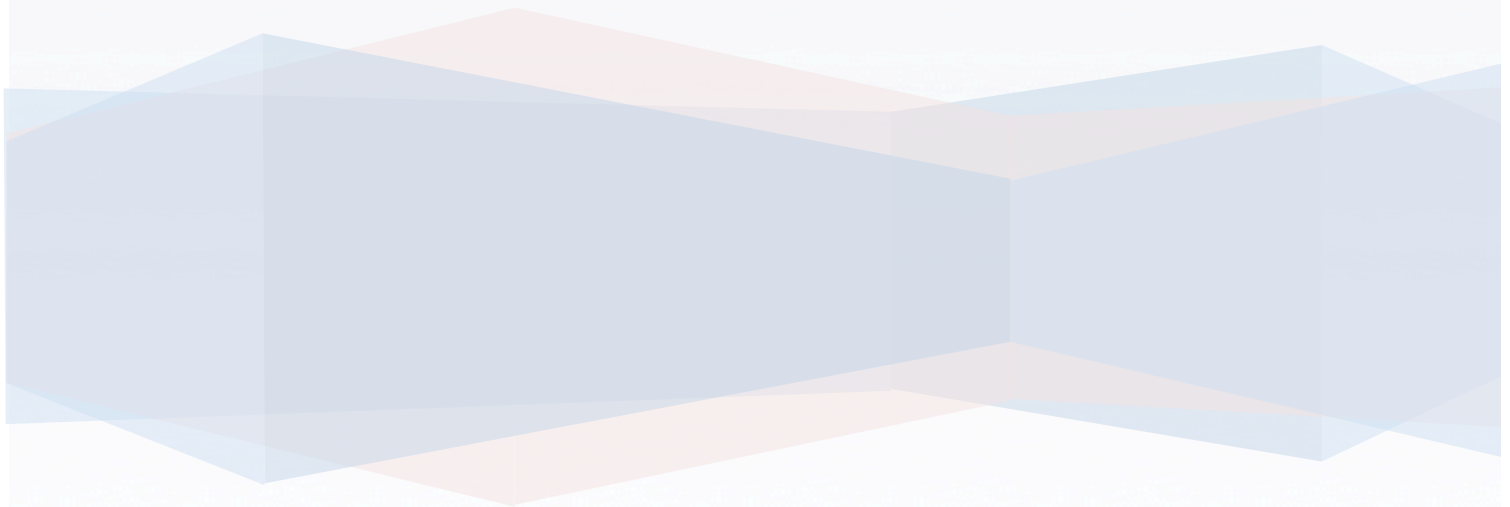
**ASELL**

Advancing Science and Engineering  
through Laboratory Learning

# ASELL Schools Science Workshop

**Experiment Manual**

Mooroolbark College, Mooroolbark



## ACKNOWLEDGEMENTS

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We would like to thank:



Department of Education  
and Training



Australian Council  
of Deans of Science



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# WELCOME

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## Welcome to 2015 ASELL for Schools Science Workshop!

ASELL (Advancing Science and Engineering through Laboratory Learning) has developed over the last 10 years. This project developed from its physical chemistry APCELL predecessor and then expanded to incorporate all of chemistry (ACELL). After successful trials of using ASELL principles at workshops in physics and biology, the project has now expanded to include biology and physics, and more recently engineering, hence the name change.

The ASELL project has been designed to help address challenges in student learning which arise in science laboratories. By bringing together diverse expertise and resources, it is possible to develop a collection of experiments, which can facilitate student learning, whilst also taking into account variations in student differences. In 2010, the first national ASELL Science Workshop was held at the University of Adelaide.

This ASELL for Schools workshop is the second Victorian workshop to be run under the Australian Mathematics and Science Partnership Funding Grant which was awarded to ASELL in 2014. This phase of the project has been initiated by Deakin University in conjunction with the University of Sydney with support from ReMSTEP and the Australian Council of Deans of Sciences. With the introduction of the new Australian Curriculum now in place, an opportunity exists to address current school-based experimentation and incorporate science inquiry. ASELL for Schools will provide the following three outcomes:

- A resource, a repository of experiments with all associated documentation necessary to run them, ranging from health and safety notes, necessary equipment and resources, notes for technical staff to the science learning objectives and how the experiment achieves them.
- Authentic professional learning workshops on experimentation in schools.
- An interface and interaction between school and university staff.

Today, you will be participating in laboratory activities and discussion sessions to expand your understanding of issues surrounding learning in the laboratory environment. In particular, it is important to be able to experience the experiments as learners.

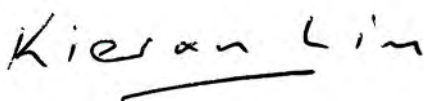
In addition to the formal program, please take the opportunity to exchange ideas about science and education and get to know each other, as an additional aim of the ASELL Schools project is to build a community of educators interested in laboratory-based education and other aspects of science education.

Up-to-date information concerning the ASELL Schools Project is provided on the project's NEW website at [www.asell.org](http://www.asell.org). The website provides public access to all experiments which have completed their testing process. Any teacher-delegate attending this workshop is entitled to an Academic user on the web site, and can request their account be upgraded using the contact form on the site. Gradually, more resources for the school sector will be added to the website.

We would like to gratefully acknowledge the efforts of the submitters in presenting their experiments, as well as the assistance of technical staff and others in making this workshop possible. A very big thank you to the team at Mooroolback College, or hosting this Workshop. Each person has put in a lot of hard work to get this workshop set up and running. I want to thank everyone!

If you have any questions about the project, please speak with me or one of the Victorian ASELL for Schools team, who are present.

Sincerely,



Kieran Lim

ASELL for Schools Victorian Leader on behalf of the ASELL for Schools Team





**ASELL**

Advancing Science and Engineering  
through Laboratory Learning

## ***Composite Materials***

**Contact: Peta White**

**[peta.white@deakin.edu.au](mailto:peta.white@deakin.edu.au)**

**Deakin University**



# Composite Materials

What could be the same between the materials used a modern racing car and surfboard?

**Racing car**



<http://www.tuvie.com/jaguar-xjr-19-lmp1-concept-race-car-for-the-year-of-2020/>

**Surfing**



<https://en.wikipedia.org/wiki/Surfing>

*Hint: focus on the how each is made (manufactured).*

## Today's Laboratory unpacks how composite materials can respond differently to unbalanced forces.

*Change to an object's motion is caused by unbalanced forces, including Earth's gravitational attraction, acting on the object (ACSSU117)*

**A composite material is made from two or more materials with different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.**

The individual components remain separate and distinct within the finished structure.

The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials.

Typical engineered composite materials include:

- Composite building materials, such as cements, concrete
- Reinforced plastics, such as fiber-reinforced polymer

## Year 7 Physical Sciences - Forces

- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

[https://en.wikipedia.org/wiki/Composite\\_material](https://en.wikipedia.org/wiki/Composite_material)

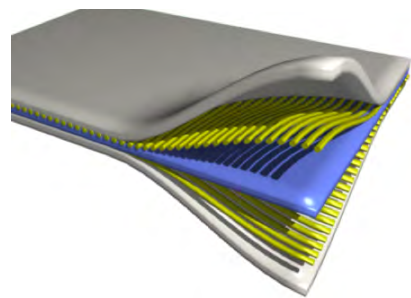
Why do we make composite materials?

■

Consider the similarity between these two pictures.



<http://www.grotecompany.com/applications/sandwich-production/>



[https://en.wikipedia.org/wiki/Composite\\_material](https://en.wikipedia.org/wiki/Composite_material)

How do you think “sandwich structure” composite materials are made?

■

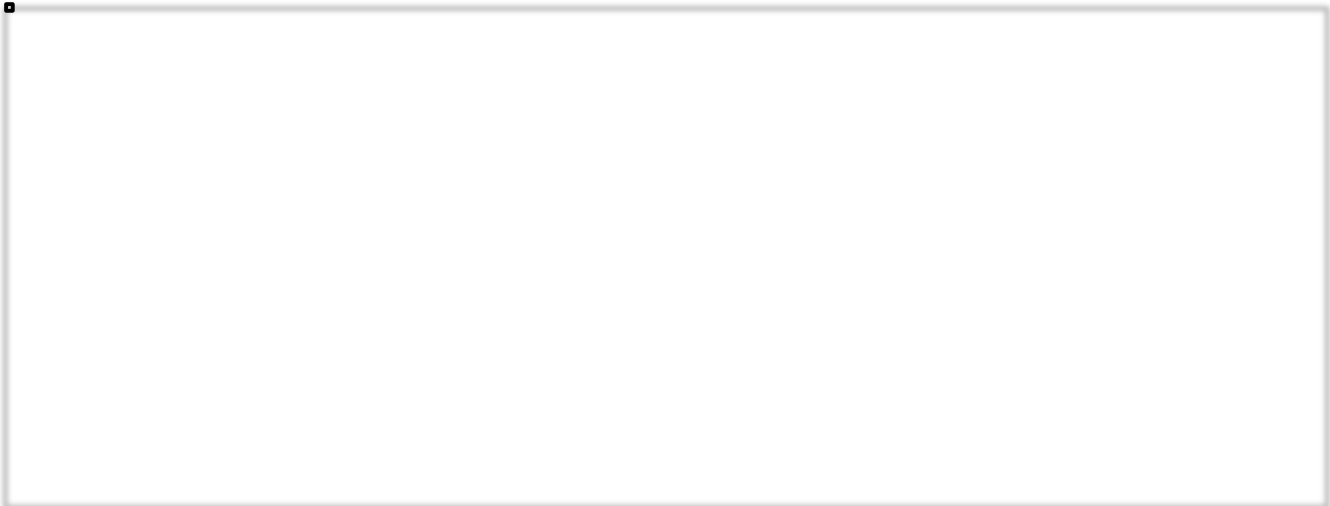
### ***Your challenge...***

Today you are a scientist who has been paid to design a stronger composite product for as little cost as possible. The following demonstration is to prepare you for the task.

Demonstration of the effectiveness of sandwich structures:

1. A polystyrene plank is not very strong.
2. When additional materials are layered onto the polystyrene it becomes a composite material and its properties change – it becomes stronger.

Draw and label the equipment and what happened

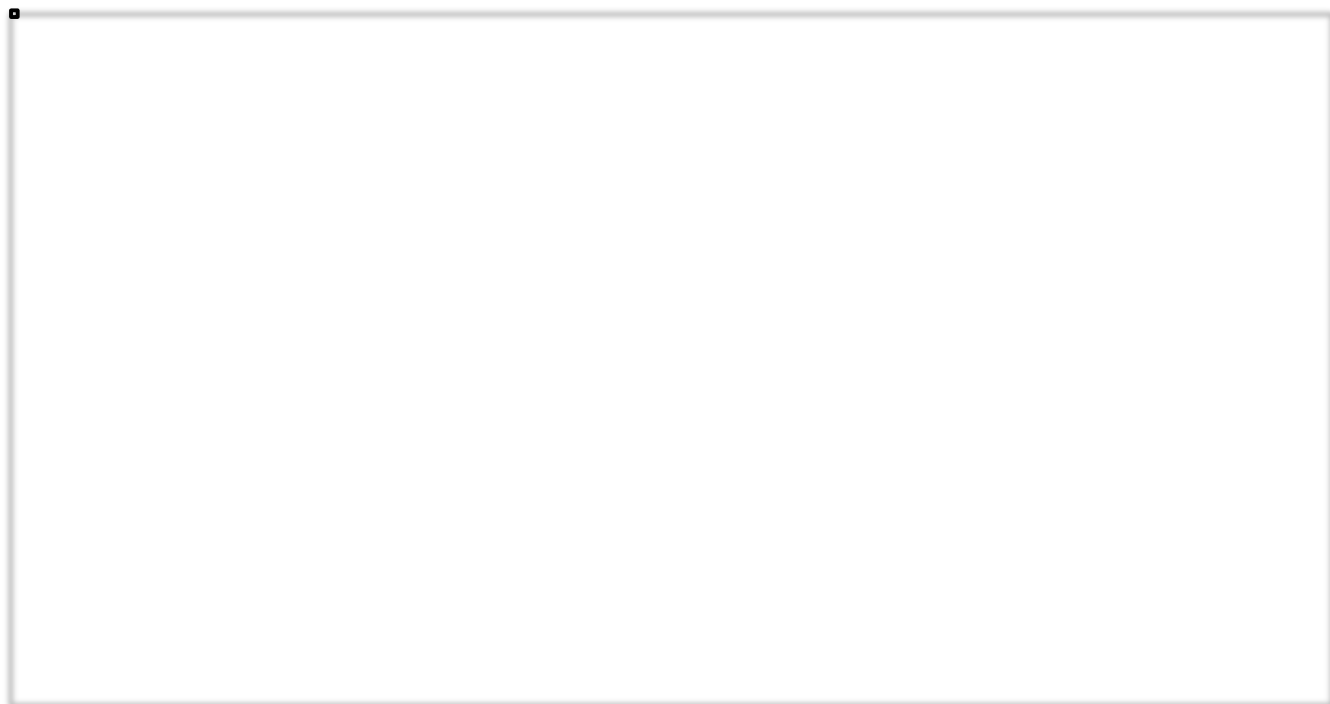


***TASK 1***

Re-do the demonstration with your group. You will need to work out a way of measuring the rigidity or how much bending there is for each individual weight added. Talk with your partner to decide how you will measure the amount of bending and record the data in the table below. Your support structures need to be 21cm apart.

| Mass (gms) | Amount of bending for Polystyrene (cm) | Amount of bending for Sandwich Structure (cm) |
|------------|--|---|
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |

Graph the data to show the difference between the polystyrene and the composite material.



## Year 7 Physical Sciences - Forces

Can you represent why you think the sandwich structure works to alter the strength and rigidity?

■



What is the role of the tape and what properties make it work well?

■



Would one piece of tape above or below the polystyrene be as effective?

■

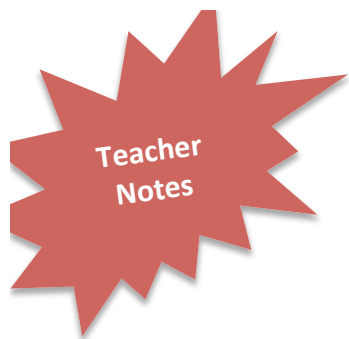


### ***TASK 2 - Challenge***

Your job as a Scientist is to create a stronger composite material using the least amount of material (polystyrene and tape) to reduce cost.

Work with your group to design to strongest sandwich structure composite material using the least tape. Test each design for strength and rigidity to decide the best design.

Decide how you will collect your data for each trial and produce a report that describes the design that works best. Include evidence (data) and an explanation as to why (using diagrams and words).



# Composite Materials

Deakin University hosts the Institute of Frontier Materials <http://www.deakin.edu.au/research/ifm/>? This Laboratory addresses some of the principles that are currently being investigated through research and design at the Institute. See at the end for details on materials.

## This Laboratory

Initial questions are designed to tune-in students. The focus here is on what the materials used to make racing cars and surfboards. Carbon fibre and fiberglass are good examples of resin composite materials. These materials are a bit tricky to use in a class so we substituted for readily available and easy to use products. We have focused on sandwich materials.

What could be the same between the materials used a modern racing car and surfboard?

### Racing car



<http://www.tuvie.com/jaguar-xjr-19-lmp1-concept-race-car-for-the-year-of-2020/>

### Surfing



<https://en.wikipedia.org/wiki/Surfing>

*Hint: focus on the how each is made (manufactured).*

The racing car is carbon fibre and a surfboard is fiberglass over polystyrene. They both use fibres set in resin to increase the strength while resulting a light product.

## Today's Laboratory unpacks how composite materials can respond differently to unbalanced forces.

Change to an object's motion is caused by unbalanced forces, including Earth's gravitational attraction, acting on the object ([ACSSU117](#))

The conceptual focus is on the unbalanced forces that result in this structure.

## Year 7 Physical Sciences - Forces

**A composite material is made from two or more materials with different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.**

The individual components remain separate and distinct within the finished structure.

The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials.

Typical engineered composite materials include:

- Composite building materials, such as cements, concrete
- Reinforced plastics, such as fiber-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

[https://en.wikipedia.org/wiki/Composite\\_material](https://en.wikipedia.org/wiki/Composite_material)

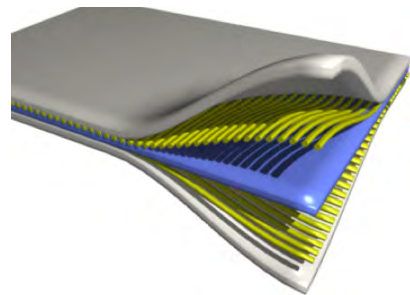
Why do we make composite materials?

These structures are stronger and lighter

Consider the similarity between these two pictures.



<http://www.grotecompany.com/applications/sandwich-production/>



[https://en.wikipedia.org/wiki/Composite\\_material](https://en.wikipedia.org/wiki/Composite_material)

How do you think “sandwich structure” composite materials are made?

Layers of materials are “glued” together.

### ***Your challenge...***

Today you are a scientist who has been paid to design a stronger composite product for as little cost as possible. The following demonstration is to prepare you for the task.

Demonstration of the effectiveness of sandwich structures:

## Year 7 Physical Sciences - Forces

1. A polystyrene plank is not very strong.
2. When additional materials are layered onto the polystyrene it becomes a composite material and its properties change – it becomes stronger.

Draw and label the equipment and what happened



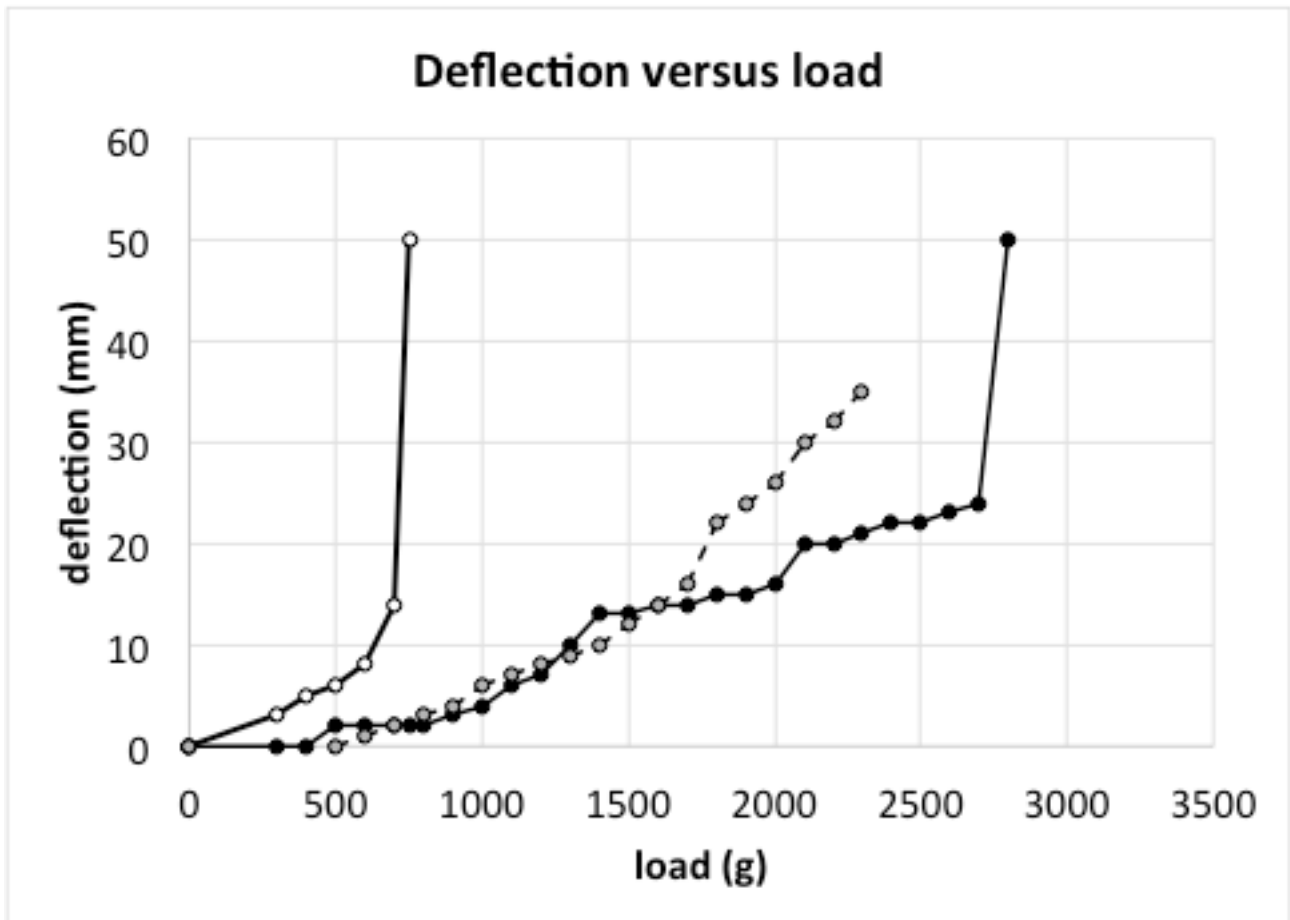
### TASK 1

Re-do the demonstration with your group. You will need to work out a way of measuring the rigidity or how much bending there is for each individual weight added. Talk with your partner to decide how you will measure the amount of bending and record the data in the table below. Your support structures need to be 21cm apart.

| Mass (gms) | Amount of bending for Polystyrene (cm) | Amount of bending for Sandwich Structure (cm) |
|------------|--|---|
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |
|            |  |   |

As the mass increases the amount of bending will also increase. The polystyrene will eventually fail (break).

Graph the data to show the difference between the polystyrene and the composite material.



The graph shows the deflection of the polystyrene (vertical axis) as load (weights, horizontal axis) are applied to the centre of the polystyrene.

The left-hand-most data (open data points) are for polystyrene with no tape. The last data point is at 750 g. The polystyrene broke with a load of 800 g.

The middle set of data (gray data points) are for polystyrene with tape on the bottom and half of the top. The last data point is at 2300 g. The polystyrene broke with a load of 2350 g.

The right-hand-most data (black data points) are for polystyrene with full-width tape on the bottom and top. The last data point is at 2800 g. The polystyrene broke with a load of 2850 g.

Can you represent why you think the sandwich structure works to alter the strength and rigidity?

This question is worth engaging in class discussion – unpack the ideas around sandwich structures and how they can increase strength and rigidity (and what are these qualities useful for?).

This is a good representation construction activity.

What is the role of the tape and what properties make it work well?

The tape provides the fibre and a glue to fuse the layered sandwich materials.

Would one piece of tape above or below the polystyrene be as effective?

One piece below is all that is needed. The top layer is ineffective at increasing the strength of the layered structure. The bottom layer could be reduced to an optimal amount (of strength for cost).

### ***TASK 2 - Challenge***

Your job as a Scientist is to create a stronger composite material using the least amount of material (polystyrene and tape) to reduce cost.

## Year 7 Physical Sciences - Forces

Work with your group to design the strongest sandwich structure composite material using the least tape. Test each design for strength and rigidity to decide the best design.

Decide how you will collect your data for each trial and produce a report that describes the design that works best. Include evidence (data) and an explanation as to why (using diagrams and words).

### Extensions to the experiment

These ideas will be developed in time.

### Background materials

#### Modern materials

Since pre-historic times humans have used naturally found materials such as wood, stone and bone as both tools and construction materials, and natural plant and animal fibres have been used for the production of clothes and other textiles. We refer to the historical period that lasted for more than three million years up until about 5,000 years ago as the Stone Age, as during that period the predominant material used by humans and our predecessors for making tools was stone. The periods following the Stone Age are generally referred to as the Bronze Age and Iron Age, with the start of each 'age' being signified by the appearance in the historical record of evidence of the production and use of these particular metals in a region of the world.

Stone is a natural material and comes in a wide range of forms, ranging from the very soft (such as Talc that is used in powder and cosmetics) to very hard (such as Granite used in building and road construction). A key difference between stone and metals such as bronze and iron is that bronze and iron are hardly ever found naturally occurring. Iron is normally found naturally as an 'ore', that is, as a chemical compound of iron and other elements. The oldest iron probably came from that found in meteorites, some of which are composed of relatively pure iron, which can be softened by heating to a high temperature and shaped into tools (wrought iron). Mixing iron ore and carbon in a high temperature furnace (smelting) produces a relatively pure form of iron that can be melted in moulds to produce shaped objects (cast iron).

Pure iron is relatively soft, and while cast iron is hard, it is also brittle and can fracture. Smelted iron can be further processed in a furnace to remove more impurities, and with the addition of small quantities of other specific elements, an iron alloy (mixture) called steel can be made. Alloying different types and amounts of additives to iron results in many possible steels with a wide range of desirable properties, including corrosion resistance and high strength. Bronze is another metal alloy, a mixture of copper (a relatively abundant but soft metal) with tin, and sometimes other elements, to produce a durable material that can be cast into shapes.

Stone is a natural material, while steel and bronze are artificial metal alloys. While stone and timber are still commonly used materials, most of the materials that you see around you today are artificial, produced by humans in industrial processes using natural raw materials, scientific knowledge and engineering know-how. Glasses, plastics, paper, many fibres and fabrics, concrete, most metal alloys, most dyes and colours, and ceramics are all common materials that are made by people because they have desirable properties that make our lives easier, safer, longer and more enjoyable.

Research by scientists leads to the discovery and creation of new materials, and engineers design both the processes which produce these materials economically, and many of the products which are made from these materials. In designing new products, engineers constantly look for ways to improve performance. This might include lower weight, lower cost, higher strength, increased safety, lower impact on the environment, and other desirable aims. The desire for improved material characteristics

drives further scientific research that might lead to refinement of existing materials, or the development of new materials altogether. The search for, and application of, new materials is a joint scientific and engineering endeavour that leads to the new and improved products that we have.

Natural fibres such as wool, cotton and silk, and metal alloys such as steel are materials that have been used for thousands of years. Never-the-less, scientific research is still going on today to refine the properties of these materials and to find new applications for them. For steel, there is an on-going quest to produce lighter, stronger steels to make cars weigh less and use less fuel without compromising passenger safety, and to reduce the time and energy required in production so that steels can be cheaper and have less environmental impacts. The processing of natural fibres uses large amounts of water and energy, and creates large volumes of waste water, and there is a desire to lower the environmental impact and cost of using natural fibres. Fabrics made from natural fibres have a range of desirable features, including being light weight, thermally insulating and in some cases water resistant. Research continues into how mimic these desirable properties in fabrics made from synthetic materials.

Steel is strong and relatively cheap because iron is a dense and abundant element. However, magnesium is also a relatively abundant metal (making up 13% of the Earth's mass), and compared to iron it is lightweight, having a density less than a quarter of that of iron. Like pure iron, pure magnesium is soft and not very strong. However, also like iron, mixing magnesium with small amounts of other elements produces alloys that are both strong and lightweight. Compounds of magnesium have been used for thousands of years, but it wasn't until the 1800s that pure metallic magnesium was first produced. This comparatively modern material remains the active subject of much scientific research to enhance its strength and formability through alloying and processing, so that it can be used in new applications where we want its strength and other desirably metallic properties combined with its light weight.

Small amounts of elements are added to some pure metals to control the internal structure of the alloys created so that they have new and more desirable properties. Perhaps the ultimate goal of materials science and engineering is to be able manipulate individual atoms or molecules to construct a material or device 'from the bottom up'. Operating on materials at very small scales is known as nanotechnology – the name coming from the prefix 'nano' in the length nanometre. Nanotechnology refers to manipulating materials or objects in the size range one to 100 nanometres – one nanometre is one millionth of a millimetre in length. Developments in nanotechnology are driven in part by the desire for more powerful computers, which requires more and more electronic devices to be placed in computer chips, which in turn requires smaller and smaller electronic devices. This challenges both our engineering ability to make these devices, but also how to connect to them with tiny nanowires, so that they can be assembled into computer products.

The other driver of nanotechnology and nanomaterials research is that materials and objects constructed at the nanoscale often exhibit new and previously unexpected properties. A sheet of single carbon atoms connected in a hexagonal pattern in a sheet and rolled into a tube ('nanotube') is the strongest and stiffest material known. Many materials are used as catalysts, because they promote certain reactions to occur – for example, platinum is used in the catalytic converter in most modern cars, to convert the toxic exhaust fumes into carbon dioxide and water. The effectiveness of a catalyst depends on the surface area available for the conversion reaction to occur on. One cubic centimetre of platinum in a single cube has an outside surface area of six square centimetres. If this is chopped into smaller one millimetre sized cubes, the available surface area increased to 60 square centimetres. If the original cube is chopped into one nanometre sized cubes, for the same volume/amount of platinum the surface area for reaction is increased to 60 million square

centimetres. On-going research into nanotechnology continues to reveal new properties of materials and new ways to engineer at very small scales.

High strength materials, like metals and concrete, are typically heavy. Historically this was less of a problem when materials and energy were relatively cheap – we could build heavy vehicles that were strong and safe, and we could have less concern about the amount of fuel used to move them around. As we move into a resource constrained world where we want to use less raw materials and energy, we look for lighter-weight materials that might replace some of the traditional materials used in the construction of buildings and vehicles, but which also offer the same or better levels of protection and strength. Composite materials are one approach to achieving the desirable lower weight and higher strength combination. A composite material is one that is ‘composed’ of two or more separate components. By carefully combining two or more materials that have some desirable characteristics, it can be possible to create a new ‘composite material’ that emphasises the desirable characteristics of the individual materials that make it up.

Lightweight strands of carbon fibre have very high strength when stretched in tension, but crumple if pushed from the sides or ends. These fibres can be set (‘cured’) into a hard plastic resin and the resultant carbon fibre composite material is lightweight and combines the tensile strength of the fibres with the rigid structure of the resin matrix when it sets solid. Carbon fibre composites are light and strong, but the raw materials used are expensive and a lot of energy is required for their production, and the curing process to produce a carbon fibre product takes a long time compared to the manufacture of similar products made from metals. Carbon fibre composites are used in applications where weight is more critical than cost, such as aircraft. Scientific research continues to find cheaper and more sustainable raw materials from which to make carbon fibres, and engineering efforts are directed at minimising the energy needed to produce the fibres and the time required to curing of products made from carbon fibre composites.

### **Modern materials research and development**

Research by scientists leads to the discovery and creation of new materials, and engineers design both the processes which produce these materials economically, and many of the products which are made from these materials. In designing new products, engineers constantly look for ways to improve performance. This might include lower weight, lower cost, higher strength, increased safety, lower impact on the environment, and other desirable aims. The desire for improved material characteristics drives further scientific research that might lead to refinement of existing materials, or the development of new materials altogether. The search for, and application of, new materials is a joint scientific and engineering endeavour that leads to the new and improved products that we have. Materials research and development (R&D) draws on many scientific disciplines, including physics, chemistry and biology. Materials R&D can be viewed from a number of levels – the level of the materials themselves (i.e., metals, plastics, steels, nanomaterials); the level of industry sectors (i.e., chemicals, construction materials, forest products); or their wider applications (i.e., health, food, energy, construction, transport).

The ability to research, develop and design with new materials is central to the plans of many developed countries to sustain their prosperity and competitiveness, to the plans of some other countries as they transition from economies based on previously abundant raw materials and/or industries in decline, and to the plans of many developing countries to help boost their development. As with much scientific research, the long-term uses and value of newly discovered materials is difficult to accurately predict, other than to say that those who can participate in and lead the R&D of new materials will almost certainly reap substantial national benefit.

## Year 7 Physical Sciences - Forces

In Australia, the federal government provides significant funding of R&D – about \$9 billion in 2014. This money supports a range of research important to the federal government (biosecurity, defence, etc.), as well as supporting more general research that is likely to bring benefits to the wider society, and hence may not be undertaken by solely commercial organisations. Government R&D funding in Australia essentially goes to universities (\$2.9B), to public sector research organisations (such as CSIRO – \$1.8B) and to the private sector in the form of tax incentives to support R&D work (\$2.1B). The remaining \$1.8B goes to support research collaboration between these sectors, such as the Cooperative Research Centre program.

While commercially operated organisations carry out most of the processing of materials and the production of goods using those materials, the R&D activity associated with materials science and technology is shared between different types of organisations. Australia's universities undertake much of the basic research in materials, producing new knowledge that may be eventually used by commercial organisations to improve their production processes and/or develop new products. Australia's largest publicly funded research organisation is the Commonwealth Scientific and Industrial Research Organisation (CSIRO - <http://www.csiro.au/>). CSIRO seeks to undertake, support and commercialise research in national priority areas, including materials. Other publicly funded research organisations in Australia with a focus on materials include Forest and Wood Products Australia (<http://www.fwpa.com.au/>), the Cotton Research and Development Corporation (<http://www.crdc.com.au/>) and Australian Wool Innovation (<http://www.wool.com/>). Tax incentives to private industry to undertake R&D work mean that the Commonwealth government will reduce the tax bill of a private company by a dollar amount equal to a proportion (currently around 40%) of the spending that the company makes on certain types of R&D work.

The Cooperative Research Centre (CRC) program is an important way in which the Australian government supports and encourages research that has strong commercial potential. CRCs are only funded when there is a significant input of funds by commercial organisations as partners in the CRC, and when the planned research activity aims to solve problems that will make Australian industry more competitive. Currently fund materials-related CRCs include the Automotive Australia 2020 CRC (<http://www.autocrc.com/>), the CRC for Advanced Composite Structures (<http://www.crc-acs.com.au/>) and the CRC for Polymers (<http://www.crcp.com.au/>). A simple view of the Australian R&D support system would suggest that universities primarily undertake fundamental (so called 'blue sky') research that, while contributing new scientific knowledge, may not have any immediate commercial application. The actual situation is a lot more complex than that. Most research funding granted to universities requires at least the consideration of the practical outcomes of the research, and many funding schemes require the involvement of industry partners, including a funding contribution from industry.

Beyond research grants supplied by the government, most universities actively seek to build partnerships with industry to share expertise and resources to solve practical problems through R&D. Research capabilities, staff and equipment are often organised into 'Centres' that focus on a specific research theme – for example the Centre for Sustainable Materials Research and Technology at the University of New South Wales (SMaRT@UNSW - <http://smart.unsw.edu.au/>) seeks to bring together university researchers and industry to develop new sustainable materials and manufacturing processes. Another way to organise research expertise at universities is via a larger 'Institute' that might combine research capacity across a number of related areas – for example, the Institute for Frontier Materials (IFM – <http://www.deakin.edu.au/research/ifm>) at Deakin University. The IFM seeks to foster innovation in materials science and engineering research, including in the following areas: metals alloy design and processing, biomaterials, corrosion protection, electrochemistry and materials, modelling of materials and processes, nanotechnology, textiles, and composite materials.

Centres, Institutes are similar groups within a university are not the only what to organise R&D resources. In composite materials science and engineering, it is possible to simply list equipment, expertise and experience related to composites R&D, such as this example from the University of Rhode Island College of Engineering in the USA:

<http://egr.uri.edu/research/composite-materials-research-development-capabilities/>

Another example is the Carbon Nexus facility at Deakin University in Australia:

<http://www.carbonnexus.com.au/>

Carbon Nexus is a part of the IFM at Deakin University, and one element of the wider composite materials R&D undertaken at Deakin University. Specifically, Carbon Nexus focusses on carbon fibre composite materials R&D, with its research priorities listed as:

1. Low cost carbon fibre
2. High performance carbon fibre
3. Surface treatment of carbon fibre
4. Advanced composite manufacturing

The Carbon Nexus facility includes advanced equipment for the production and testing of carbon fibre composite materials, and also a team of materials scientists and engineers who specialise in carbon fibre composites R&D. Carbon Nexus undertakes R&D that is funded through all of the mechanisms noted above, with a focus on industry collaboration and industry funded R&D.



**ASELL**

Advancing Science and Engineering  
through Laboratory Learning

***Which metal is best for food and drink  
storage?***

**Contact: Amanda J Peters**

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**Mooroolbark College, Manchester Road, Mooroolbark, 3138**

# WHICH METAL IS BEST FOR FOOD AND DRINK STORAGE?

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PRESENTED BY AMANDA PETERS – MOOROOLBARK COLLEGE

## ASELL EDUCATIONAL TEMPLATE – SECTION 1 (SUMMARY OF THE EXPERIMENT)

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### **1.1 Experiment Title**

Which metal is best for food and drink storage? (Formerly: reaction of acid with metals)

### **1.2 Introduction and Description of the Experiment**

Substances may be created by chemical change and may also undergo chemical change.

### **1.3 Reasons for Submission**

The experiment is a standard experiment in many textbooks and has been used at the College for several years. However, the metals are mostly unreactive and therefore there is not a lot of student engagement with this practical exercise. We have tried using more concentrated acid, however, this can become a safety risk for Year 9 students.

The ASELL for Schools team have suggested modifications, to improve both the scientific and educational outcomes.

The November 2016 workshop is the first time the modified practical will be run in a class or class-like setting.

### **1.4 Experiment Aims and Objectives**

The aim of the activity is to investigate the chemical reaction(s) of an acid with a range of metals. Students should observe that the metals exhibit a range of reactivities – some react vigorously and evolve a relatively large amount of gas, while others are unreactive.

Unlike the regular versions of this experiment, students are not told that hydrogen is generated. Students need to work out what gas is produced. Secondly, the experiment is placed in a context which requires students to investigate the reactivity of different metals.

This difference in reactivity can also be linked to energy transfer in the learning sequence.

### **1.5 Level of the Experiment**

The level of the experiment is Year 9, which is Level 9 in the *Victorian Curriculum: Science* (Note <sup>1</sup>).

The main learning outcome is (Note <sup>2</sup>):

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<sup>1</sup> Victorian schools can choose to use *AusVELS* or the *Victorian Curriculum F–10* in 2016. *AusVELS* will be archived in December 2016, and replaced by the *Victorian Curriculum F–10*.

<sup>2</sup> *Victorian Curriculum: Science*, level 9  
<http://victoriancurriculum.vcaa.vic.edu.au/level9?layout=1&d=S>.

- Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (VCSSU126)

Secondary learning outcomes are (potentially):

- The ... properties of elements are used to organise them in the periodic table (VCSSU123)
- ... chemical reactions ... can occur at different rates; chemical reactions may be represented by balanced chemical equations (VCSSU125)
- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (VCSSU115)
- The values and needs of contemporary society can influence the focus of scientific research (VCSSU116)
- Analyse patterns and trends in data, including ... identifying inconsistencies in data ... and drawing conclusions that are consistent with evidence (VCSIS138)
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (VCSIS140)

Note that the main learning outcome is slightly different from that in the former *AusVELS* because the *Victorian Curriculum: Science* directly and explicitly links chemical reactions with energy transfer.

### **1.6 Keyword Descriptions of the Experiment**

Domain keywords: chemistry, chemical reactions

Specific Descriptors: chemical change, acid, metal.

### **1.7 Course Context and Students' Required Knowledge and Skills**

This experiment is within the 'chemical reactions' unit at Year 9 level, particularly focusing on acids and bases.

Students will have previously learned the following knowledge and/or acquired the following skills:

- the particle model
- how to look for and describe observations of chemical reactions
- chemical change involves substances reacting to form new substances
- how to write word equations
- identifying reactants and products
- conduct scientific investigations using a fair test

### **1.8 Time Required to Complete**

|                   |            |
|-------------------|------------|
| Prior to Lab:     | 10 minutes |
| In Laboratory:    | 25 minutes |
| After Laboratory: | 20 minutes |

**1.9 Authors of Educational Analysis**

Kieran F Lim (Deakin University) and Amanda J Peters (Mooroolbark College)

**1.10 Experiment History**

In the school setting, this experiment had little success in terms of obvious reactivity with only two of five metals tested reacting. This experiment is an important experiment as it allows students to observe and describe the reactions of metals with acid. It also has many other learning opportunities for students, including: observe and describe reactions, create an order of reactivity and link this to the periodic table, conceptualise why and how the reaction is occurring, write word and chemical equations, link these reactions to ‘real-life’ examples. The fundamental concepts of this experiment will be needed for future science endeavours, particularly when studying chemistry.

In the revision of this experiment, the basic textbook-based “recipe” experiment was put into an investigative context (which metal is best for food and drink storage), based on an experiment in a book on Guided Inquiry Experiments for General Chemistry by Kerner and Lamba.

Other changes to the experiment were proposed by the *ASELL for Schools* and the *ReMSTEP* teams. (Note <sup>3</sup>)

**1.11 Any Other Comments****Some Possible Inquiry Questions:**

Using acids and metals to ‘build’ batteries (electric cells), using any of: combinations of metals; amount of metal; concentration of acid.; making a battery with a number of cells in series and compare with cells in parallel.

**Possible Extension for lower year levels:**

Use this as a demonstration for making observations and placing different reactions in order of reactivity.

**Possible Extension for higher year levels:**

1. Compare the results to the periodic table. Is there a pattern with the results and where the metals are placed on the periodic table? Suggest a reason why.
2. Choose different metals to compare reactivity. Hypothesise the expected results and test.

**1.12 References**

Kerner, N., & Lamba, R. (2008). *Guided Inquiry Experiments for General Chemistry: Practical Problems and Applications*. New York: John Wiley and Sons.

Lofts, G. Evergreen, M. (2015). *Science Quest 9 for Victoria*. Australian Curriculum Edition. Milton (Qld): Jacaranda. p. 283

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<sup>3</sup> *ReMSTEP: Reconceptualising Mathematics and Science Teacher Education Programs through collaborative partnerships between scientists and educators* <<http://remstep.org.au/>> accessed on 19 November 2015.

## SECTION 2 – EDUCATIONAL ANALYSIS

Note: Starred outcomes are those that are the principal focus of the exercise. Non-starred outcomes may either be less important, or be outcomes, which could be the focus of the experiment if it were modified. Please restrict yourself to no more than 10 outcomes, with no more than 5 starred, and include at least one outcome in each section.

| Learning Outcomes         |     | Process                     | Indicators   |
|---------------------------|-----|-----------------------------|--|
| What will students learn? | (*) | How will students learn it? | <i>How will teachers <b>and</b> students know that the students have achieved the learning outcomes?</i> |

**2.1 Theoretical and Conceptual Knowledge**

|   |   |  |  |
|---|---|--|--|
| Some metals will react with acid to produce dissolved substance(s) and hydrogen gas | * | Some metals will dissolve (seem to disappear) while generating a gas, which ignites with a “pop”.                | Students are able to describe and explain their observations using pictures (representations) and/or words (word equations). |
| Metals have a range of reactivities with acid                                       | * | Different metals are mixed with acid to observe their reactivities   | Some metals react with acid, some very vigorously and some less vigorously; other metals have no observable reaction         |
| The reactivities of different metals are related to energy of reaction              | * | As an extension exercise, students will build a battery using a piece of fruit and two metals as the electrodes. | The best choice of the metals as the electrodes will be the metals that are most and least reactive when reacted with acid   |

**2.2 Scientific and Practical Skills**

|  |   |  |  |
|--|---|--|--|
| Students can create and complete and perform a planned procedure   | * | Creating and/or following steps in the procedure                                       | Successfully completing the experiment   |
| Communication – with each other in the group.                      | * | Students will communicate with each other to coordinate teamwork and to discuss ideas. | Students are able to coordinate their various tasks in a cooperative manner. Students participate in discussions with each other and with the teacher to arrive at conclusions that was consistent with other scientific concepts. |
| Observation – detailed and accurate. Working in cooperative groups | * | Students will perform tests and record their observations                              | Observations will be recorded and shared with the class.   |

| Learning Outcomes         |     | Process                     | Indicators   |
|---------------------------|-----|-----------------------------|--|
| What will students learn? | (*) | How will students learn it? | <i>How will teachers <b>and</b> students know that the students have achieved the learning outcomes?</i> |

### 2.3 Thinking Skills and Generic Attributes

|  |   |   |  |
|--|---|---|--|
| Students can rank the reactivities of different substances | * | Students observe the vigorous-ness (rate or speed) of different metals reacting with acid | Students produce a ranking that is consistent with their own observations and those of other students, and with “textbook” information such as the position of particular metals in the periodic table |
|--|---|---|--|

LABORATORY EXERCISE

---

## Which metal is best for food and drink storage?

### Introduction

---

A local company plans to use some of their excess metal to produce cans for food and soft drink storage. They are aware that some metals are highly reactive on contact with the acids in food while others are not. They have asked for your help in sorting the group of metals based on their reactivity. The company asks you to recommend one or more metals for can production.

### Materials

---

- Safety glasses
- Apron or laboratory coat
- Bench mat
- Test tubes and test-tube rack
- Pieces of metal – sodium, calcium, magnesium, aluminium (source 1), aluminium (source 2), zinc, copper
- Dropping bottle containing  $2 \text{ mol L}^{-1}$  hydrochloric acid solution
- Rubber stoppers
- Matches

### Method

---

Different foods and drinks contain a variety of acids, including acetic acid (vinegar), citric acid (a component of orange and lemon juice), ascorbic acid (vitamin C), phosphoric acid (found

in soft drinks), benzoic acid (a preservative) and other acids. In this experiment, hydrochloric acid (the main component of digestive acid in the stomach) will be used as a typical acid in order to have a standardised test.

Some metals might react with hydrochloric acid to produce a gas. Hydrochloric acid in water is made from hydrogen, oxygen and chlorine, so they are the possibilities for any observed gas. A lighted match can be used to distinguish between these gases.

- If hydrogen gas is present, the lighted match will ignite the hydrogen gas, making a popping sound.
- If oxygen gas is present, the lighted match will flare up.
- If chlorine gas is present, the lighted match will be extinguished.

- 1. Clean a piece of metal (for example, zinc or magnesium) with sandpaper.**
- 2. Place a small piece of the metal in a test tube.**
- 3. Add hydrochloric acid to the test tube to a depth of 1 cm.**



CAUTION!

Do not push the stopper into the test tube firmly. Just hold it in the top of the test tube for few seconds.

- 4. Gently hold a rubber stopper over the end of the test tube for a few seconds and then placing a lighted match at the mouth of the test tube.**

N.B.

Your observations should make use of as many senses as possible. Was there a change in appearance? Was there a change in temperature? Was there a sound?



CAUTION!

Do not test for changes in smell or taste.

- 5. Record your observations table provided (see below). If possible, take a photo of each result.**
- 6. Repeat steps 1-5 for the other metals.**
- 7. If possible, determine a ranking of the metals from least reactive to most reactive.**

## Results

[illegible]

The order of reactivity from least reactive to most reactive is:

|  |
|--|
|  |
|--|

### Discussion

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List three safety rules you should follow in this experiment.

|    |
|----|
| 1. |
| 2. |
| 3. |

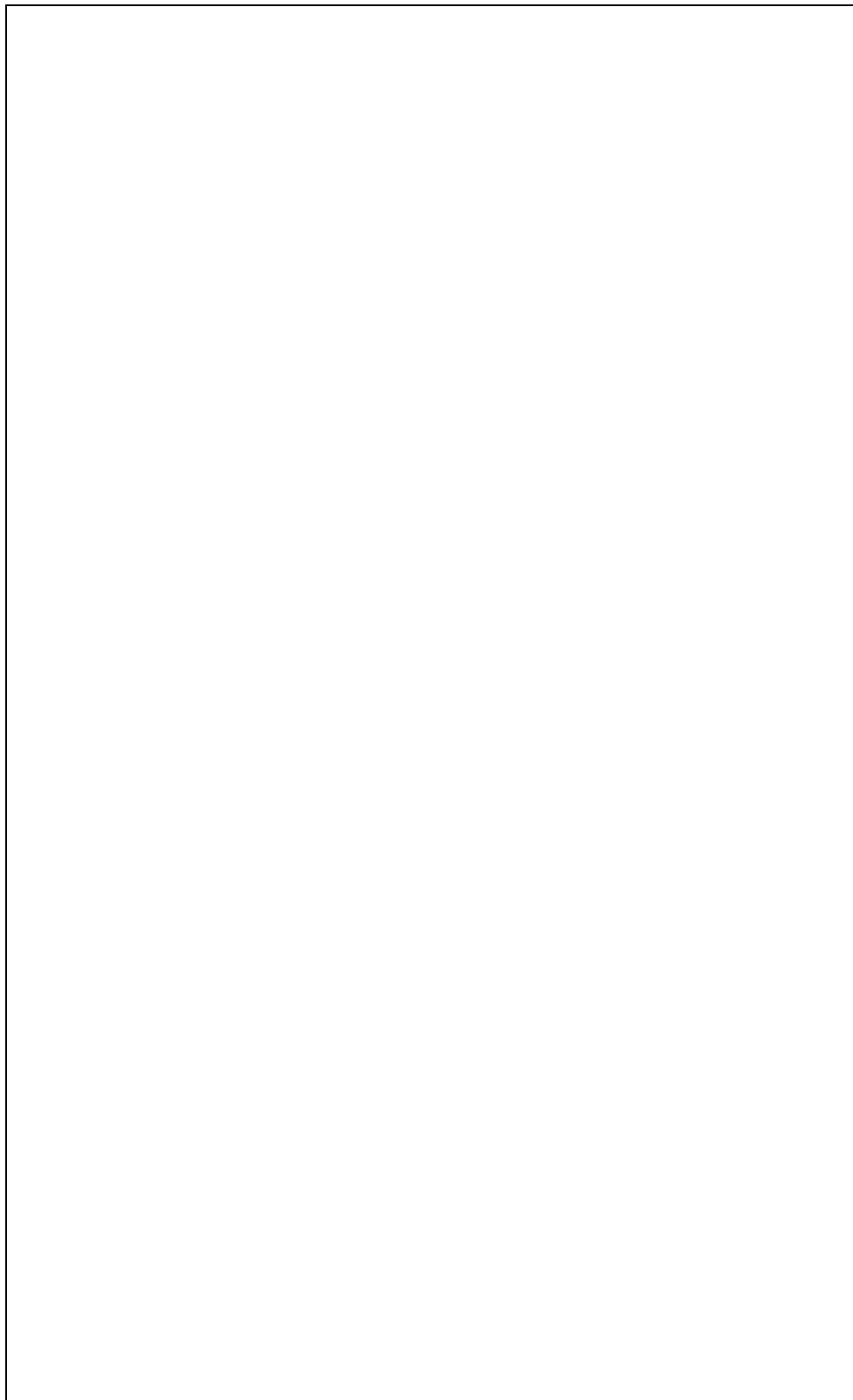
What is the aim of this experiment? What scientific question are you trying to answer?

|  |
|--|
|  |
|--|

How did you determine the order of reactivity of metals?

|  |
|--|
|  |
|--|

What do you think is happening in the test tube to make the chemical reaction? Draw a picture, with labels, explaining your answer.



When zinc metal reacts with hydrochloric acid, zinc chloride and a gas are formed. (Hint: what did you determine to be the gas?) Write a word equation to describe this reaction.

If any of your reactions produced a 'pop' with the lighted match test, hydrogen gas reacted with oxygen in the air to form water. You may have noticed the water form at the top of the test tube after you performed the match test. Write a word equation for this chemical reaction.

Did you notice any difference in reactivity for the two types of aluminium? If so, please suggest a reason for any difference.

Based only on the reactivity of metals with acid, which metal or metals would be best for food and drink storage?



TEACHER NOTES

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## Which metal is best for food and drink storage?

### Background

---

This practical activity is a variation on the standard “acid plus metal” experiment found in most textbooks.

Acid + metal  $\rightarrow$  hydrogen gas + dissolved metal chloride.

Indeed, students carry out exactly the same experimental procedures as in the standard experiment.

A local company plans to use some of their excess metal to produce cans for food and soft drink storage. They are aware that some metals are highly reactive on contact with the acids in food while others are not. They have asked for your help in sorting the group of metals based on their reactivity. The company asks you to recommend one or more metals for can production.

### Learning outcomes

---

At the end of this practical activity, students should

- Be able to make accurate observations of a reaction
- Know that hydrogen gas is produced by an acid plus metal reaction
- Know that various metals have different reactivities when mixed with hydrochloric acid.

## Links to the Victorian Curriculum F–10

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The main learning outcome is:

- Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (VCSSU126)

Secondary learning outcomes are (potentially):

- The ... properties of elements are used to organise them in the periodic table (VCSSU123)
- ... chemical reactions ... can occur at different rates; chemical reactions may be represented by balanced chemical equations (VCSSU125)
- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (VCSSU115)
- The values and needs of contemporary society can influence the focus of scientific research (VCSSU116)
- Formulate questions or hypotheses that can be investigated scientifically, including identification of independent, dependent and controlled variables (VCSIS134)
- Analyse patterns and trends in data, including ... identifying inconsistencies in data ... and drawing conclusions that are consistent with evidence (VCSIS138)
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (VCSIS140)

## Extensions

---

This experiment is intended for year 9.

This experiment can be extended by including a further inquiry question:

Using acids and metals to 'build' batteries (electric cells), using any of: combinations of metals; amount of metal; concentration of acid.; making a battery with a number of cells in series and compare with cells in parallel.

Possible extension for lower year levels:

Use this as a demonstration for making observations and placing different reactions in order of reactivity.

Possible extension(s) for higher year levels:

1. Compare the results to the periodic table. Is there a pattern with the results and where the metals are placed on the periodic table? Suggest a reason why.
2. Choose different metals to compare reactivity. Hypothesise the expected results and test.

# RISK ASSESSMENT FORM

Experiment /Process

Reactions of Acids with Metals.  
p 266. Quest 9.



Year Level

8/9

Name of Assessor (Print Name) JUDY LACKMAN

Date 5/9/14

| HAZARDOUS SUBSTANCE        | STATE<br>(S/L/G) | Corrosive | Poison | Irritant | Carcinogen | Mutagen | Teratogen | Route of Entry |      |           |             | MSDS Date |
|----------------------------|------------------|-----------|--------|----------|------------|---------|-----------|----------------|------|-----------|-------------|-----------|
|                            |                  |           |        |          |            |         |           | Skin           | Eyes | Ingestion | Respiratory |           |
| Hydrochloric acid 2M       | L                | ✓         |        | ✓        |            |         |           | ✓              | ✓    | ✓         | ✓           | Oct '12   |
| Magnesium ribbon - NonHaz. | S.               |           |        | ✓        |            |         |           | ✓              | ✓    |           |             | Jun '11.  |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |
|                            |                  |           |        |          |            |         |           |                |      |           |             |           |

## Hazardous Products

|  |  |  |  |  |  |  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|--|--|--|--|--|
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

## CONTROLS

|                  |                  |        |             |                            |
|------------------|------------------|--------|-------------|----------------------------|
| SAFETY GLASSES ✓ | Apron/Lab Coat ✓ | Gloves | Exhaust Fan | Wash hands at conclusion ✓ |
| Work in Fumehood |                  | Other  |             |                            |

## Disposal of Waste

Safe for sewerage system

Collect for disposal ✓

OTHER HAZARDS eg:

Spillage

Splashes

Flammability

Burns

stains

Wash with copious amounts of water.

Are existing controls suitable and maintained?

YES

NO

If not, What is required?

LONG TERM

SHORT TERM



**ASELL**

Advancing Science and Engineering  
through Laboratory Learning

## ***Using acids and metals to build 'batteries'***

**Contact: Amanda J Peters**

**[peters.amanda.j@edumail.vic.gov.au](mailto:peters.amanda.j@edumail.vic.gov.au)**

**Mooroolbark College, Manchester Road, Mooroolbark, 3138**



LABORATORY EXERCISE

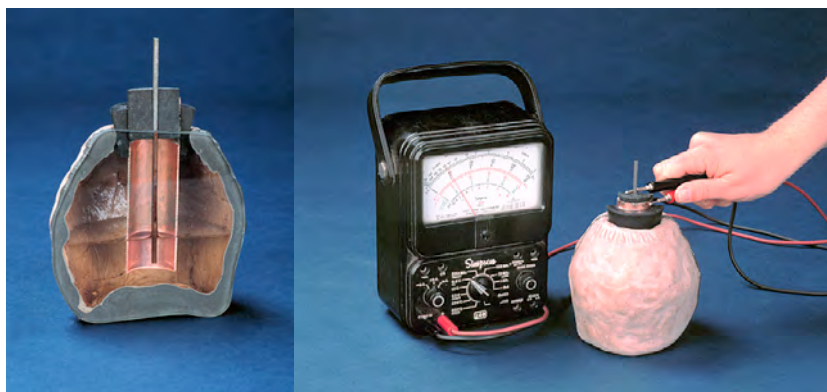
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## Using acids and metals to build ‘batteries’

### Introduction

---

The term Baghdad Battery is used to refer to three artifacts, which were found together: a ceramic pot, a tube of one metal, and a rod of another. The current interpretation of their purpose is as a storage vessel for sacred scrolls from nearby Seleucia on the Tigris. Those vessels do not have the outermost clay jar, but are otherwise almost identical. (Note <sup>1</sup>)



Photographs from The Virtual Museum of Ancient Inventions  
(Note <sup>2</sup>)

There is some speculation that these jars were actually ancient batteries. The Museum of Ancient Inventions has asked you to investigate whether two pieces of metal immersed in fruit juice can make a battery.

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<sup>1</sup> “Baghdad Battery”, Wikipedia <[https://en.wikipedia.org/wiki/Baghdad\\_Battery](https://en.wikipedia.org/wiki/Baghdad_Battery)> accessed on 19 November 2015.

<sup>2</sup> D. Downs and A. Meyerhoff, “Battery, Baghdad, 250 BCE”, The Virtual Museum of Ancient Inventions, Smith College, Northampton (MA)  
<[http://www.smith.edu/hsc/museum/ancient\\_inventions/battery2.html](http://www.smith.edu/hsc/museum/ancient_inventions/battery2.html)> accessed on 19 November 2015.

## Materials

---

- Safety glasses
- Apron or laboratory coat
- Bench mat
- Fruit
- Different types of metals (magnesium, aluminium, zinc, copper)
- Ammeter (including milliammeter or microammeter) or LED or incandescent light bulb
- Connecting leads with alligator clips
- Knife
- Chopping board

## Background

---

In a previous investigation you examined whether a mixture of acid and metal would result in reaction. It was found that some acid-metal mixtures did react according to the processes:

EQUATION 1

Acid + metal  $\rightarrow$  hydrogen gas + dissolved substance(s) .

Other acid-metal mixtures did not react.

We can think of Equation 1 as involving two processes, both of which occur simultaneously:

EQUATION 2

- (a) metal  $\rightarrow$  dissolved substance(s) + electrons  
 (b) electrons + other dissolved substance(s)  
 $\rightarrow$  undissolved neutral compound

In the previous investigation you found that the undissolved neutral compound in the 2<sup>nd</sup> process was hydrogen gas, but in general, it could be some other undissolved neutral compound, depending on what is in the reaction mixture.

## Aim and hypothesis

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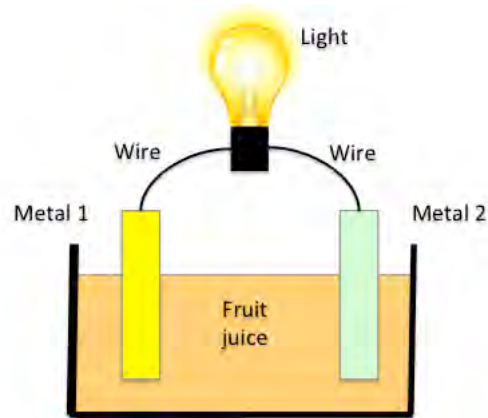
What do you think is the aim and hypothesis of this experiment?

Based on the results of your previous investigation, which metal(s) do you think would react most easily (quickly) by the reaction in Equation 2(a)?

HINT

The reaction in Equation 2(b) looks like the opposite or reverse of the reaction in Equation 2(a).

Based on the results of your previous investigation, which metal(s) do you think would react most easily (quickly) by the reaction in Equation 2(b)?



A simple battery powering a light bulb

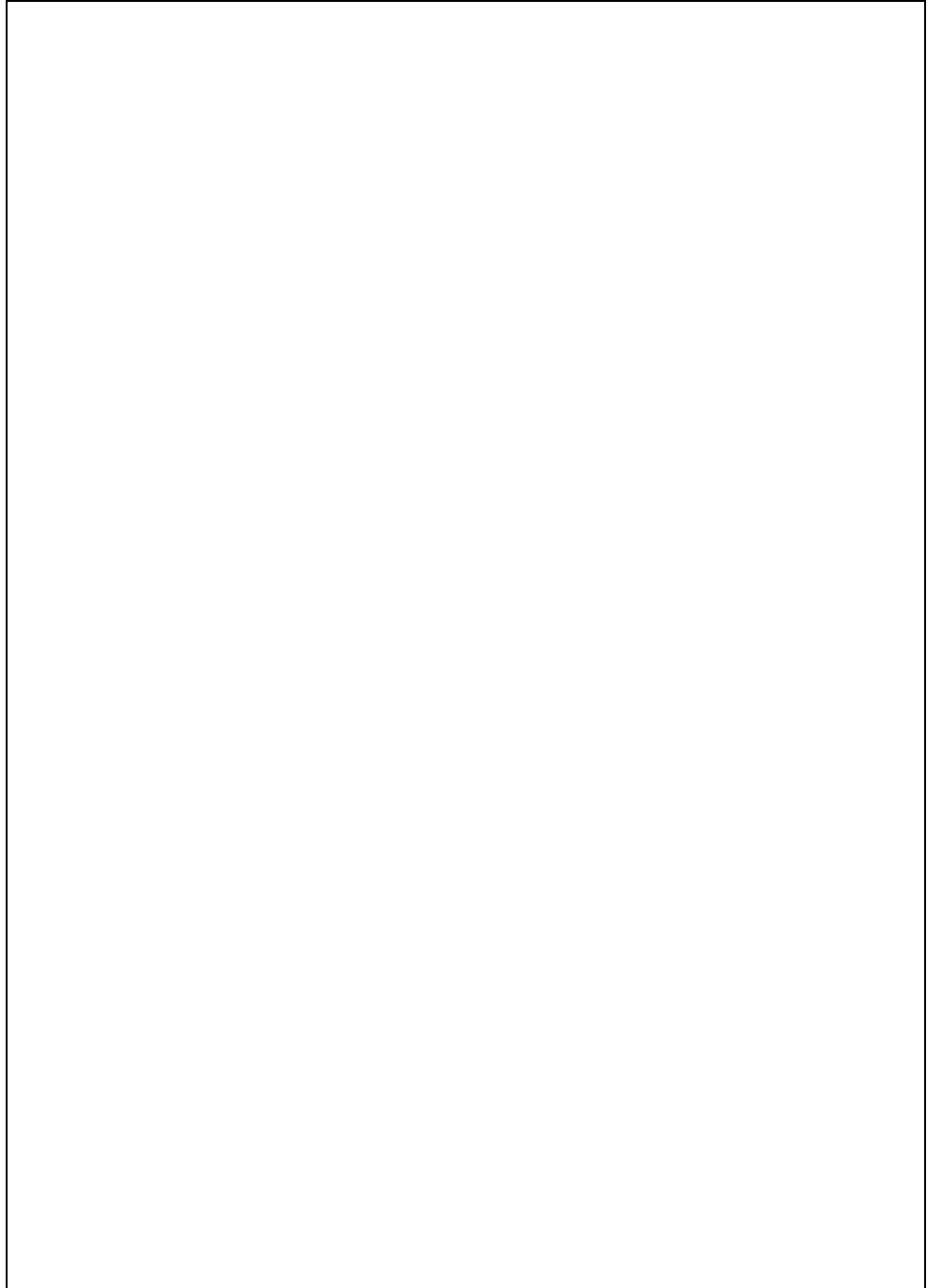
Based on the answers to the previous two questions, which combination of metals do you think would most likely be combined to make a battery?

## Method

---

1. Choose your fruit.
2. To create an electric cell, you will need to insert two different types of metals into the fruit, you may need a knife to cut a slit into the fruit so the metal can be inserted. The metals will need to be about 3cm apart.
3. Connect the metals to the microammeter or LED using connecting leads, to make an electric circuit. If the dial goes to the left on the microammeter, swap the leads. Experiment with your set up to create the highest current or brightest LED light.

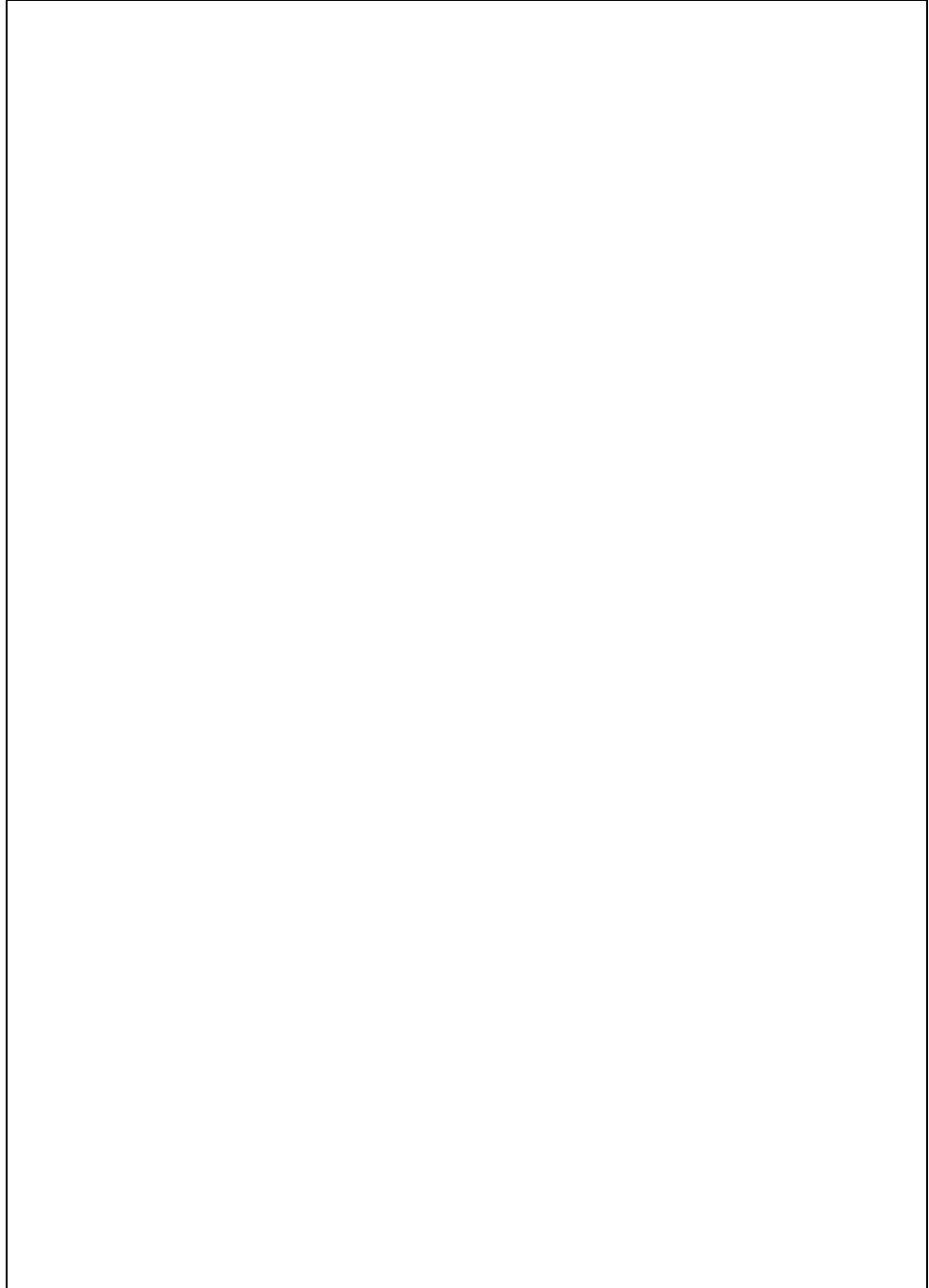
4. Draw a picture of this set up, including the positive and negative terminals if you using a microammeter. Label your drawing.



## Discussion

---

Use a drawing to explaining how you think the electricity is made.

A large, empty rectangular box with a thin black border, intended for a student to draw and explain how electricity is made.

Did the result of your experimental test agree with the combination of metals that you thought would most likely to make a battery?

Briefly discuss why the result of your experimental test did (or did not) agree with the combination of metals that you thought would most likely to make a battery?



TEACHER NOTES

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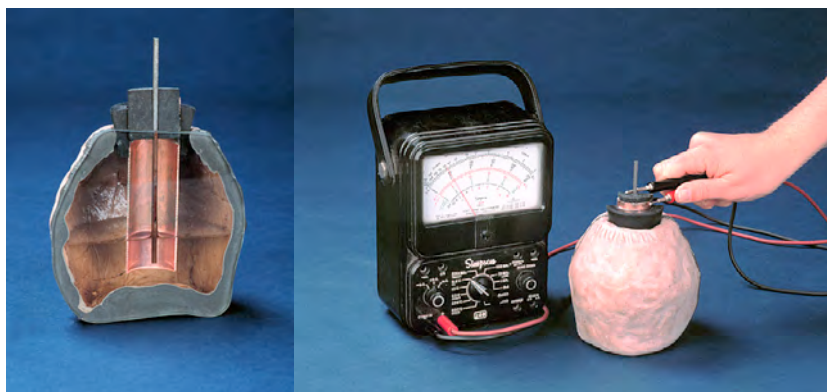
## Using acids and metals to build ‘batteries’

### Introduction

---

This practical activity is a variation on the standard galvanic cell experiment found in many textbooks. Instead of using a salt bridge with two separate half-cells, a single combined cell (piece of fruit) is used.

The term Baghdad Battery is used to refer to three artifacts, which were found together: a ceramic pot, a tube of one metal, and a rod of another. The current interpretation of their purpose is as a storage vessel for sacred scrolls from nearby Seleucia on the Tigris. Those vessels do not have the outermost clay jar, but are otherwise almost identical. (Note <sup>1</sup>)



Photographs from The Virtual Museum of Ancient Inventions (Note <sup>2</sup>)

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<sup>1</sup> “Baghdad Battery”, Wikipedia <[https://en.wikipedia.org/wiki/Baghdad\\_Battery](https://en.wikipedia.org/wiki/Baghdad_Battery)> accessed on 19 November 2015.

<sup>2</sup> D. Downs and A. Meyerhoff, “Battery, Baghdad, 250 BCE”, The Virtual Museum of Ancient Inventions, Smith College, Northampton (MA) <[http://www.smith.edu/hsc/museum/ancient\\_inventions/battery2.html](http://www.smith.edu/hsc/museum/ancient_inventions/battery2.html)> accessed on 19 November 2015.

There is some speculation that these jars were actually ancient batteries. The Museum of Ancient Inventions has asked you to investigate whether two pieces of metal immersed in fruit juice can make a battery.

### Technical tip 1

---

HINT!

Before inserting any metal electrodes, it is best to gently squeeze the lemon (or orange). Do this gently so the skin of the lemon doesn't rupture. Rolling it on a table with a little pressure works great.

### Technical tip 2

---

HINT!

A single lemon with copper and iron (steel) electrodes generates about 0.7 V, but only about 1 mA. Two lemon batteries in series will generate about 1.5 V, but still only about 1 mA. This is **not** enough current for an incandescent light bulb. (Note <sup>3</sup>)

### Learning outcomes

---

At the end of this practical activity, students should

- Be able to make accurate observations of a reaction
- Know that hydrogen gas is produced by an acid plus metal reaction
- Know that various metals have different reactivities when mixed with hydrochloric acid.

### Links to the Victorian Curriculum F–10

---

The main learning outcome is:

- Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (VCSSU126)

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<sup>3</sup> California Energy Commission (2006), "Lemon Power", Energy Quest, California Energy Commission <<http://www.energyquest.ca.gov/projects/lemon.html>> accessed on 19 November 2015.

Secondary learning outcomes are (potentially):

- Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104)
- ... chemical reactions ... can occur at different rates; chemical reactions may be represented by balanced chemical equations (VCSSU125)
- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (VCSSU115)
- Formulate questions or hypotheses that can be investigated scientifically, including identification of independent, dependent and controlled variables (VCSIS134)
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (VCSIS140)

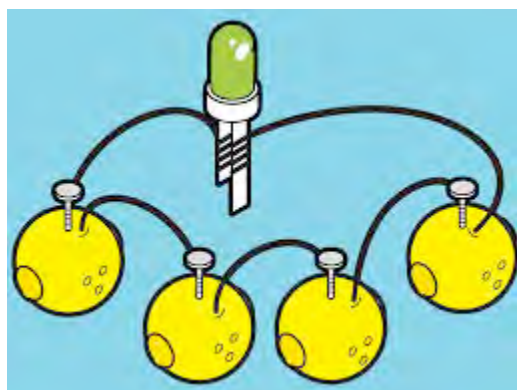
## Extensions

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This experiment is intended for year 9.

Once the fruit battery has been established, it is possible to add more electrodes either in parallel or in series, which then addresses a different learning outcome:

- Electric circuits can be designed for diverse purposes using different components; the operation of circuits can be explained by the concepts of voltage and current (VCSSU130)



## parallel circuit

<[https://en.wikipedia.org/wiki/Lemon\\_battery](https://en.wikipedia.org/wiki/Lemon_battery)>

## series circuit

<<http://makezine.com/projects/batteries-from-everyday-things/>>

Further investigations can include:

1. Investigate the effect on the electric current of cutting up the fruit into pieces. If you do this, you will need to place the pieces of fruit side by side (in series).
2. Insert the (same) two different metals into each piece of cut fruit and connect the different metals using the leads. Experiment with the positioning of the two metals and terminals.
3. Which set up gives the greatest electric current or brightest LED? Draw a picture of this set up.
4. Include a drawing, explaining how you think the electricity is generated. Discuss your suggestions with the group next to you.
5. How did the cut pieces of fruit, making a series circuit, change the electric current? Why do you think this is?
6. You were advised gently squeeze the lemon (or orange) before inserting any metal electrodes. Briefly explain why this is so.
7. Where do you use batteries in everyday life?