2.1 What is a metal?

Lesson outcomes

At the end of this activity students will be able to:

- explain the properties of metals in terms of the arrangement of electrons in the crystal lattice
- describe the distribution of metals in the periodic table
- investigate the properties of common metals.

What ideas might your students already have?

Students should recall the common properties of metals from Stage 4 and Year 9 Science.

Key vocabulary:

Transition metal.

Equipment list

Each PAIR will require:

- samples of iron, copper and zinc (see Hints)
- emery paper
- density cubes of iron, copper and zinc
- dropper bottles solutions of:
- dilute hydrochloric acid (see note in Hints)
- iron (II) sulfate (Fe^{2+} ions)
- copper (II) sulfate (Cu^{2+} ions)
- zinc (II) sulfate (Zn^{2+} ions)
- sodium hydroxide (OH- ions)
- sodium carbonate (CO_3^{2-} ions)
- sodium chloride (Cl- ions)
- spotting tile or plastic sheet
- beam/electronic balance
- 250 mL beaker
- 3 test tubes and rack
- hot plate

Each STUDENT will require:

- *Science by Doing Student Digital*
- safety glasses

Things to consider and hints for success:

Practical: comparing transition metals

- Choose metal samples that illustrate properties of malleability and ductility, such as small manufactured objects e.g. screws, bolts, wires etc. Small pieces of each element are also needed for the acid test.
- In dilute acid, zinc will react when cold (bubbles of hydrogen evolved), iron will react in warm acid, whereas copper does not react with dilute acid.
- Note: If students are only allowed to handle 1M acid then a teacher demonstration using 2M acid will give a better differentiation of relative reactivities of metals.
- The densities of the metals are: zinc 7, iron 8 and copper 9 g/cm^3.
- There are no precipitates with chloride ions. Carbonate and hydroxide ions should give precipitates for all three elements. Examples of equations are:

  $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Fe(OH)_{3\,(s)}$

  $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2\,(s)}$

  $2Fe^{3+}_{(aq)} + 3CO_3{}^{2-}_{(aq)} \rightarrow Fe_2(CO_3\,)_{3(s)}$

  $Cu^{2+}_{(aq)} + CO_3{}^{2-}_{(aq)} \rightarrow CoCO_{3\,(s)}$

Lesson plan

Step 1: Brainstorm metallic properties, linking this to the stimulus material in *Science by Doing Student Guide*. Students deduce the reasons for the properties in terms of electron configuration and arrangement of atoms in metals.

Step 2: Pairs investigate the properties of transition metals, following the instructions in the guide.

Step 3: A class discussion of the experiment and to check equations for the reactions indicated.

Step 4: Students form groups, using the roll-over activity in *Science by Doing Student Digital* and on-line links, to discuss the ***Notebook*** questions

Suggested questions:

- Why are the electrons in metals able to move freely?
- Explain how this allows them to:
  - conduct heat
  - conduct electricity
  - be malleable (bent into different shapes)
  - be ductile (pulled into wires).

Follow up:

An understanding of metal properties is the basis for the rest of the activities in this topic.

2.2 Activity series of metals

Lesson outcomes

At the end of this activity students will be able to:

- undertake first-hand laboratory investigations to compare the reactivity of a variety of metals
- describe the properties of metals in terms of the structure and arrangement of atoms in crystal lattices.

What ideas might your students already have?

Students should realise that metals vary widely in their reactivity from previous science topics in Year 7-9.

Key vocabulary:

Lattice.

Equipment list

Each PAIR will require:

- small pieces of calcium, copper, iron, lead, magnesium, tin, zinc and aluminium
- dropper bottle of dilute hydrochloric acid (se Hints)
- 7 test tubes
- test-tube rack
- hot plate
- 250 mL beaker (water bath)
- emery paper
- 10 mL measuring cylinder.

Each STUDENT will require:

- *Science by Doing Student Digital*
- safety glasses.

Things to consider and hints for success

Practical – reactivity of metals: Students should only attempt the reactions with water and dilute acid as suggested. **Note**: If students are only allowed to handle 1M acid then a teacher demonstration using 2M acid will give a better differentiation of relative reactivities of metals.

Teacher demonstrations with warm 4M hydrochloric acid could be added to differentiate between less reactive metals that do not bubble in warm 2M acid, e.g. lead, copper and tin.

Aluminium can appear less reactive than its position in the activity series due to an unreactive coating of aluminium oxide, which quickly forms when it is exposed to air.

Remind students of the reactivity of sodium compared to the metals used here (from demonstrations in **Part 1**).

Lesson plan

Step 1: Brainstorm why some metals are found as the element in nature, while others occur only as compounds. This could be recorded on butcher paper (or a smart board) to be referred to later. Also review the reaction/equation for the metals with water/acids.

Step 2: Pairs follow the *Science by Doing Student Guide* to complete the practical activity.

Step 3: When students have attempted the discussion questions, review the reactions and compare the order of reactivity suggested by different pairs, reaching a consensus.

Step 4: Students use the interactive diagrams in *Science by Doing Student Digital* to compare the reactivity of the elements with their own data.

Step 5: In groups, students discuss the ***Notebook*** questions.

Follow up:

Reactivity is linked to extraction of metals from their ores in subsequent **Part 3** activities.

2.3 Metals from ores

Lesson outcomes

At the end of this activity students will be able to:

- investigate the activity of a range of metals to deduce their relative order of reactivity
- write equations to represent displacement reactions
- describe the relationship between the reactivity of a metal, its occurrence in nature and how it is extracted from ore.

What ideas might your students already have?

Students may have little awareness of the fact that pure metals have to be extracted from rocks and minerals.

Key vocabulary:

Displacement, ore, native metal.

Equipment list

Displacement of metals

Each PAIR will require:

- 4 small pieces each of copper, iron, magnesium and zinc metals
- dropper bottles of copper sulfate, iron (II) sulfate, magnesium sulfate and zinc sulfate solutions
- 4 test tubes
- test-tube rack.

Copper from copper oxide

Each GROUP will require:

- small quantity of copper (II) oxide powder
- hard glass test tube or ignition tube
- spatula
- charcoal powder
- Bunsen and heat mat
- safety glasses
- hand lens or dissecting microscope

Lead from lead nitrate

Each PAIR will require:

- lead nitrate solution (see Hints for use of lead compounds)
- 2 cm piece of shiny magnesium metal
- small test tube in rack.

Each STUDENT will require:

- *Science by Doing Student Digital*
- Safety glasses.

Things to consider and hints for success

This lesson could be split into two shorter periods.

Demonstration of a silver tree: students enjoy this demonstration of a displacement reaction in which silver is displaced from solution by copper. http://www.unitednuclear.com/silvertree.htm

The equation for this reaction is: $Cu_{(s)} + Ag^{+} \rightarrow Cu^{2+}{}_{(aq)} + Ag_{(s)}$

Using lead compounds: ensure students know lead can be absorbed through the skin and do not touch lead compounds. Disposable gloves could be worn and hands should be washed afterwards.

Copper from copper oxide: oxygen combines with the carbon in the test tube to reduce the metal, and carbon dioxide and carbon monoxide are produced.

e.g. $2CuO_{(s)} + C_{(s)} \rightarrow 2Cu_{(s)} + CO_{2(g)}$

Teacher content information:

A displacement reaction: in which one element displaces another in a compound or solution. In metal displacement reactions, if a more reactive metal is placed in a solution containing the ions of a less reactive metal, it will ionise into the solution. The less reactive metal will be displaced to form a solid.

Displacement reactions are usually represented by ionic equations:

e.g. $Mg_{(s)} + Pb^{2+}{}_{(aq)} \rightarrow Mg^{2+}{}_{(aq)} + Pb_{(s)}$

Lesson plan

Step 1: Discuss what the class understands from **Activity 2.2** about the relationship between reaction rate and occurrence of metals in nature.

Step 2: Pairs complete the displacement practical activity, following instructions in the *Science by Doing Student Guide*. Conclude with a class discussion of the order of reactivity and equations.

Step 3: Demonstration of silver tree (see **Things to consider and hints for success**) and discussion of displacement reactions .

Step 4: Students complete investigations to obtain metals by heating and displacement reactions, following *Science by Doing Student Guide* instructions (see **Things to consider and hints for success**)

Step 5: Use *Science by Doing Student Digital* to consider the occurrence of metals worldwide and the significance of metals mined in Australia.

Step 6: Students use on-line links, individually or in groups, to further investigate displacement reactions and their significance in obtaining metals. This could be used for extension activities or homework.

Suggested questions:

- Give an example of a native element? How were they named?
- Explain what happens in a displacement reaction?
- Which of the two metals (less or more reactive) must be in the solution for the reaction to work?

Follow up:

Methods of extraction of more reactive metals and the link between reactivity and corrosion are discussed in subsequent **Part 2** activities.

2.4 Electrolysis

Lesson outcomes

At the end of this activity students will be able to:

- safely construct, assemble and manipulate equipment to carry out electrolysis
- use cause and effect relationships to explain ideas
- summarise information to describe the main points.

Key vocabulary:

Electrolysis, electrolyte, electrode, anode, cathode.

Equipment list

The CLASS will require:

- samples of 'malachite' ore: This can be made as follows:
  - mix equal amounts of copper carbonate powder and plaster of Paris
  - add water and mix to a thick paste
  - quickly mould into small pieces about 2 cm in diameter
  - dry overnight.

Each GROUP will require:

- copper ore (1-2 cm across)
- filter funnel and paper
- 250 mL beaker
- 50 mL beaker
- conical flask
- pestle and mortar
- wash bottle
- dilute sulfuric acid
- Bunsen burner, tripod and gauze
- 2 carbon electrodes
- power pack and leads
- small iron nail.

Each STUDENT will require:

- safety glasses
- *Science by Doing Student Digital*
- ***Notebook***

Things to consider and hints for success:

Note: A better reaction occurs with 2M sulfuric acid than with 1M acid, if students are permitted to handle this.

Lesson Plan

Step 1: Use the stimulus material in *Science by Doing Student Guide*, with the periodic table, to review the positions and patterns of reactive metals that can be separated from compounds using electrolysis. Review the process using the diagram of electrolysis of molten sodium chloride.

Step 2: Discuss the cell used to purify copper on page 27 of the guide, ensuring students know the terms anode and cathode and what happens at each electrode. (The electrolysis video and Daniell cell animation could now be shown.)

Step 3: Students summarise key points about electrolysis and draw a representative diagram of an electrolytic cell.

Step 4: Copper can be extracted in groups of three or four following the instructions in the guide.

Step 5: After exploring the interactive on copper extraction in the *Science by Doing Student Digital*, students use their practical observations and the digital links to answer the ***Notebook*** discussion questions.

Suggested questions:

- Why is electricity needed to obtain reactive metals from their ores?
- What is an electrode?
- What happens at the cathode/anode?

Follow up:

Similar processes involving electrolytic cells will be used in **Activity 2.7**.

2.5 Metals we use

Lesson outcomes

At the end of this activity students will be able to:

- describe specific uses of metals linked to their unique properties
- select and extract data from appropriate digital technologies
- describe how alloys can enhance the properties of metals.

What ideas might your students already have?

Students should be able to identify the properties that distinguish elements as metals.

Key vocabulary:

Alloy.

Equipment list

Each GROUP will require:

- internet
- objects made of alloys e.g. pewter mug, stainless steel cutlery, brass candlestick, solder, tungsten drill bit – see table below.

Things to consider and hints for success:

Titanium – periodic table of videos (8'): (see **Activity 3.7, Find out more**) titanium properties, uses and why it is difficult to extract.

Alloys: Australian coins are made of the following alloys:

Silver coins: (cupronickel) 25% nickel, 75% copper.

Gold coins: 92% copper, 6% aluminium, 2% nickel.

Useful information on composition and uses of alloys:

alloy	composition	properties	uses
bronze	90% copper 10% zinc	hard, shiny, does not corrode easily, shiny surface	statues, medals, artwork
brass	70% copper 30% tin	harder than copper, easy to machine, ductile, polishes well	screws, bolts, musical instruments, machinery parts, kitchenware, electrical parts, ornaments
cupronickel	75% copper 25% nickel	shiny surface, does not corrode easily, hard wearing, resistant to sea water	'silver' coins, propellers, pipes and other marine hardware
structural steel	95% iron 0.5% carbon	hard, strong	bridges, vehicles, girders, rails

alloy	composition	properties	uses
tungsten steel	71% iron 24% tungsten 5% chromium	very hard and heat resistant	industrial tools and machinery, saw blades, drill bits
stainless steel	74% iron 8% carbon 18% chromium	shiny, strong, does not corrode easily	cutlery and bowls, surgical instruments, sinks, pipes
Duralumin	93% aluminium 3% copper 3% magnesium 1% manganese	light, strong, does not corrode	aircraft bodies and engine parts
pewter	96% tin 3% copper 1% antimony	shiny, strong, does not corrode	utensils, jewellery
9-carat gold	37.5% gold 11% silver 51.5% copper	shiny, strong, easily worked, does not corrode, attractive gold colour	jewellery
titanium	83% titanium 7% niobium (not medical alloys) 6% aluminium 4% vanadium	very strong, light, high melting point, resistant to corrosion	aircraft frames, spacecraft, body implants e.g. bone and dental
Sterling silver	92% silver 8%copper	easily worked, harder than pure silver, unreactive, attractive silver colour	jewellery, ornaments
solder	63% lead 37% tin	low melting point, sets quickly	soldering joints in metal pipes and copper wires

Lesson plan

Step 1: Brainstorm metal properties on a **Mind Map** and their uses linked to these properties. The class should record a summary (or print from smart board).

Step 2: Class discussion of "*Why titanium is special?"* using stimulus material from *Science by Doing Student Guide*. '*Titanium- periodic videos*' fit in well here (see **Things to consider and hints for success**). Pairs consider research question and report to the class.

Step 3: Use the *Science by Doing Student Guide* material page 30 to investigate the structure of alloys and their properties. Show samples. For homework, students should research the composition of Australian coins**.**

2.6 Corrosion

Lesson outcomes

At the end of this activity students will be able to:

- identify factors that affect the corrosion of metals
- describe methods of reducing corrosion
- investigate factors affecting corrosion
- design a controlled experiment to collect valid first-hand data.

What ideas might your students already have?

Students should recognise corrosion as one of the reaction types they have studied and have some ideas about its cause.

Key vocabulary:

Corrosion, dehydrate.

Equipment list

Each GROUP will require:

Comparing corrosion

- pieces of aluminium, iron and copper
- clear nail varnish.

Corrosion in seawater

- 4 test tubes
- 4 iron nails (not galvanised)
- sodium chloride solution (or sea water)
- 5 cm piece of clean magnesium ribbon
- 5 cm piece of copper wire
- test-tube rack
- marking pen
- distilled water.

Things to consider and hints for success:

Setting up group experiments:

It is important to allow time for students to set up the two experiments and prepare in their ***Notebooks*** to collect results over the next week.

Time to write up the experiments and discuss findings will also be needed at the end of **Part 2**. Some could be done as homework.

Link: The video below (*Science by Doing Student Digital* **Activity 2.7**) could be used here to discuss or review corrosion but perhaps watched in part, or by students at home, as it is long.

- **Corrosion Chemistry** (28'): It covers iron manufacture, corrosion, a summary of activity series and methods of protection, e.g. galvanizing, sacrificial anode. Corrosion protection is covered in more depth in **Activity 2.7**.

Teacher content information:

Possible options for preventing corrosion are:

- **Painting –** provides a protective coating but it can be easily scratched and broken, allowing the metal underneath to corrode. This can be expensive, as the object must be repainted frequently.
- **Modifying the environment** - e.g. keeping dry, reducing humidity.
- **Oiling –** a cheap protective coating, but must be repeated frequently.
- **Galvanising –** iron is dipped in molten zinc to form a thin coating which is more reactive and prevents corrosion.
- **Non-corrosive alloys –** adding elements such as carbon and chromium to iron reduces the reactivity of the iron atoms.
- **Sacrificial anode –** an anode made from a reactive metals e.g. zinc or magnesium reacts to prevent metals such as iron rusting.
- **Anodising aluminium –** a layer of aluminium oxide is built up using electrolysis to protect the metal surface.

Lesson plan

Step 1: Discuss why some metals corrode and others do not, drawing on what students have learnt about reactivity and the stimulus material in *Science by Doing Student Guide*. Brainstorm ways to reduce corrosion and their effectiveness. Students record as a summary.

Step 2: Students work in groups to set up the experiment ‘Comparing corrosion rates’ and draw up a table in their ***Notebooks*** to make observations over the next week.

Step 3: Use the *Science by Doing Student Guide* page 32 to review the chemical reactions involved in corrosion, before student groups set up the ‘Corrosion in seawater experiment’ and draw a table to record their observations over the next week.

Follow up:

Give students a few minutes in the next few lessons to record observations on the two experiments and about 30 minutes to complete their reports and discuss their findings after **Activity 2.7**.

2.7 Protecting metals

Lesson outcomes

At the end of this activity students will be able to:

- anodise and electroplate an object
- describe how electrolytic processes protect metals
- evaluate information from secondary sources to consider the future use of metals.

Key vocabulary:

Galvanise, anodise, sacrificial anode, electroplate.

Equipment list

Each PAIR will require:

Electroplating

- 20 cent coin
- strip of zinc foil
- metal tongs
- dilute nitric acid (see note in Hints)
- zinc sulfate solution
- emery paper
- power pack
- 150 mL beaker
- 2 leads with alligator clips
- wash bottle of distilled water.

Anodising aluminium

- aluminium foil
- piece of aluminium plate
- dilute sulfuric acid (see note in Hints)
- 2 x 250 mL beakers
- emery paper
- dye solution
- detergent
- retort stand and clamp
- hot plate
- power supply, leads and alligator clips

Each STUDENT will require:

- *Science by Doing Student Digital*
- safety glasses.

Things to consider and hints for success

This lesson can be split into two shorter periods.

Note: A better reaction occurs with 2M acid than 1M acid, if students are permitted to handle this.

Lesson Plan

Step 1: Review the previous lesson before discussing protection methods, such as galvanising and sacrificial anodes, using the stimulus material in the *Science by Doing Student Guide*.

Step 2: Students complete the electroplating activity in pairs, then compare results with the class, and answer the discussion questions.

Step 3: Ask groups to think of aluminium objects they have at home, linking to how anodising works and why anodised objects can be different colours.

Step 4: Pairs complete the anodising activity in pairs, then compare their product with other students as they complete the discussion questions.

Step 5: The *Science by Doing Student Digital* can be used for consolidation and to help students to answer the ***Notebook*** questions.

Step 6: Students complete the multiple-choice quiz to review the topic.