

Mathematics Science Strand
Physical Science

**Module
P3**

Useful materials and reactions



Student Support Material

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Unit overview

(Based on the National Curriculum Guidelines)

The shaded Module represents the one studied in these materials.

Unit	Code	Module
Physical Science	P1	Structure of matter
	P2	Energy
	P3	Useful materials and reactions
	P4	Physical Concepts and Machines
	P5	Waves

Symbols used in these materials.

The symbols shown in the table indicate the type of activity to be completed while studying this module.



Read or research



Write or summarise



Activity or discussion



Safety note

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Module P3 Useful Materials and Reactions

Rationale

We use many chemical substances, both natural and manufactured, in our daily lives. There are many useful chemicals and substances around us. Some of these may be used directly while others need to be processed or changed to be useful, e.g., soap is made from fat and caustic soda. Many reactions occur in nature as a day to day process. Some reactions are necessary to sustain life while others are a nuisance, such as rusting of iron and corrosion of outboard motors. In this module you will study a selection of useful substances and some reactions associated with those substances.

The teaching and learning strategies should include a range of activities that relate directly to common substances and the utilisation of these substances for human endeavour, both in a modern and traditional setting. Activities should cater for students' prior knowledge and abilities. Students should be engaged in such a way that they relate the theory directly to their surroundings.

Objectives

At the end of this module students should be able to

- (a) *Describe why some molecules are essential to life;*
- (b) *list a number of useful metals and describe their uses and chemical properties*
- (c) *explain the processes of corrosion such as rusting;*
- (d) *describe ways to prevent corrosion;*
- (e) *list useful non-metals and describe their importance in everyday life;*
- (f) *list the major types of chemical reactions that affect useful substances;*
- (g) *provide examples of reaction types with reference to the chemical properties of common and everyday substances;*
- (h) *investigate locally available chemical substances;*
- (i) *describe a number of useful organic substances and their properties and uses;*
- (j) *perform experiments safely to investigate the physical and chemical properties of a number of common substance.;*

Introduction

We use many chemical substances, both natural and manufactured, in our daily lives. There are many useful chemicals and substances around us. Some of these may be used directly while others need to be processed or changed to be useful, e.g., soap is made from fat and caustic soda. Many reactions occur in nature as a day to day process. Some reactions are necessary to sustain life while others are a nuisance, such as rusting of iron and corrosion of outboard motors. In this module you will study a selection of useful substances and some reactions associated with those substances.

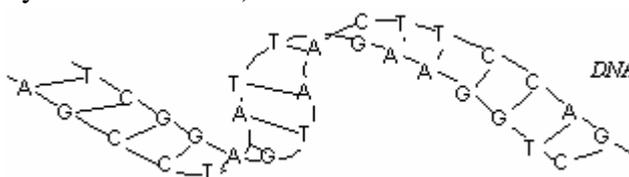
Some substances are essential to life.

Molecules of Life

The four atoms which make up most of our bodies are hydrogen, oxygen, nitrogen and carbon. Of these, the special one is carbon. Carbon has the ability to form chains and rings by joining onto other carbon atoms. This gives rise to the great variety of 'organic' compounds, the compounds that make up the cells of living things and others based on carbon. Some simple carbon-based molecules are:

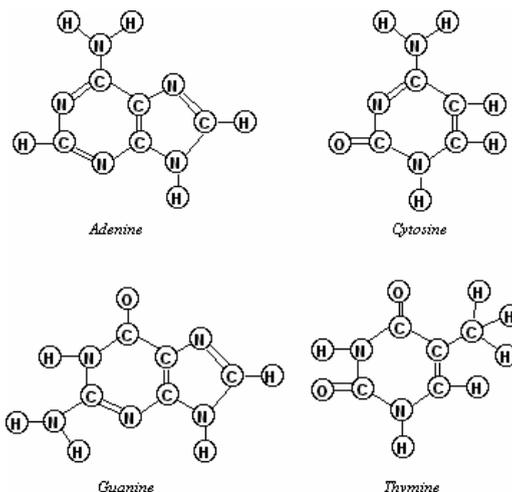
In 1858, the chemist Friedrich August Kekulé (1829–1896) discovered that carbon had a valency of 4 and could link with itself forming long chains. This was the basis for structural organic chemistry. He discovered the 'benzene ring' in 1865. He knew there were six carbon and six hydrogen atoms in the molecule from chemical analysis, but how could they be connected? He had a dream of a snake eating its tail. When he woke the next day the idea of the benzene ring came to him.

The molecule DNA (deoxyribonucleic acid) forms the basis for life as we know it. It is contained in the nucleus of every cell in our bodies and carries the genetic code, the plans for



making the whole human body passed on by the parents. Rosalind Franklin took the first X-ray photograph of a DNA molecule. It was her work that enabled Watson and Crick to discover that the structure is a double helix. (Watson and Crick never acknowledged the work that Franklin did towards the discovery of the DNA structure.) A helix is the shape the thread on the outside of a bolt or screw has. A double-helix is a double thread. The chromosomes are long DNA molecules. They know how to uncoil, separate into two separate threads and each one makes its own matching thread. That is how DNA reproduces. It is a living molecule. Even though DNA is such a long molecule, it is made of groups of atoms called bases. There are only four:

Thymine (a vitamin) bonds loosely with adenine, and cytosine bonds loosely with guanine. A “gene” is a pattern of bases in a particular order in a particular place in a molecule of DNA, e.g., 1700 base pairs form the code for making the hormone insulin.



Ozone

You have heard of the ‘ozone layer’ and know that it protects the earth from harmful ultraviolet radiation from the sun. The gas ozone is found concentrated in the ozone layer, which is present over the north and south poles at an altitude of 25km.

The ozone molecule is formed when energy is absorbed by oxygen molecules causing them to break apart and the atoms of oxygen join in threes instead of twos.

The oxygen molecule has two linked oxygen atoms. Ultraviolet from the sun breaks apart some of these molecules in the upper atmosphere, and they link with other oxygen molecules forming ozone, O₃:

The smell after lightning comes from the ozone formed around the lightning discharge. Electricity breaks the oxygen molecules apart in a similar way to electrolysis breaking apart water molecules.

Ozone’s smell was first noticed in 1785. Ozone as a gas was discovered in 1840, but it had to wait until 1872 before its chemical formula was discovered.²

Silicones

Silicon is an element, which can form chains in a similar way to carbon. Silicones are compounds similar to organic (carbon-based) chain molecules. They are not found in nature, only in the laboratory. Very, very long chain molecules made of simple repeating parts are called polymers. Some silicones are oily liquids (such as in breast implants) while others are used as synthetic rubber. Silicone is added to furniture and car polish to give a glossy shine.

1. Useful metals and their reactions

Society has used many natural chemical substances for its benefit since prehistory. For example, during the *Bronze Age* civilisations discovered that copper ores could be heated with charcoal to produce copper metal. This metal was then alloyed easily with tin to produce bronze, an alloy of tin and copper. The *Iron Age* was based on the discovery of the way to extract iron metal from iron ores. This discovery led to rapid development of implements of war: knives, swords, lances, canons and lastly rifles.

Not all discoveries were put to such destructive use. Metals have always been used for decorative purposes such as jewellery. For example, gold, silver, copper and bronze have been fashioned into things to wear or idolise for the past few thousand years.

A **metal** is an element in which the atoms are bonded by a sea of electrons. That is the electrons are free to move. The other important feature of metallic bonding is the packing of the atoms. This is just like stacking marbles or balls of the same size. They will either pack in a cubic or hexagonal arrangement as shown in figure 1.

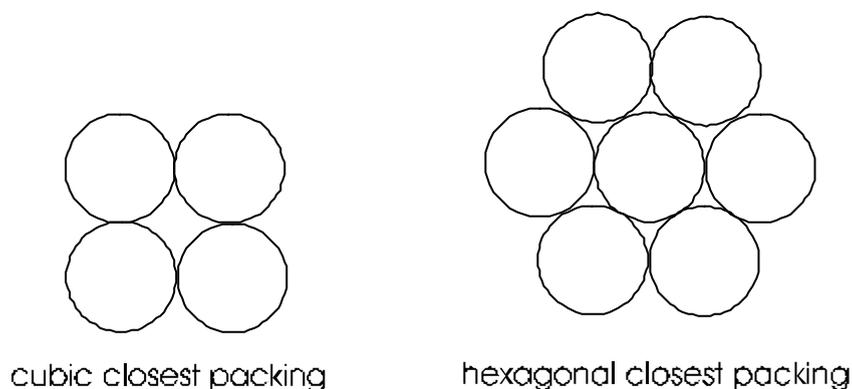


Figure 1. Packing arrangements of atoms in metals

Why are we able to shape metals fairly easily?

Metallic bonding is not as strong as ionic or covalent bonding. This allows the metal atoms to “slip” past one another. On a larger scale metals reflect this property in being malleable and ductile. The sea of electrons as shown in figure 2 enables metals to conduct electric charge easily. In some metals the bonding is a bit stronger or the electron configuration is different therefore they don’t conduct electricity as well, e.g., iron is a poorer conductor than copper.

Why do metals conduct electricity so well?

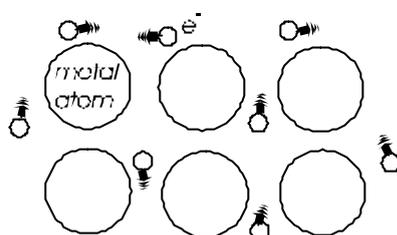


Figure.2 Free electrons

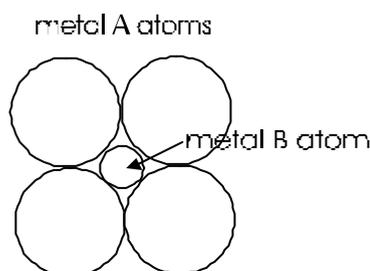
surround metal atoms

When light strikes the surface of a metal much of the white light is reflected giving many newly cut or polished metals a silvery appearance. Some metals show colours due to absorption of some colours and reflection of the colours we see. This reflection of light is called ***lustre***.

Why do many metals have a shiny appearance?

An ***alloy*** is a homogeneous mixture of two or more different metals. This means that the different metal atoms have packed in a regular way to produce a new packing arrangement such as shown in figure 1.3. It is this new arrangement that changes the properties of the original parent metals. For example lead and tin are both very soft metals yet ***solder***, an alloy of lead and tin, is much harder and therefore useful in plumbing in joining zinc plated metals. Tin and copper are both very soft metals however the alloy of tin and copper, ***bronze***, is very tough. Bronze is used for bushes and bearings particularly in ships.

Figure 3 An alloy with a metal B atom fitting inside 4 metal A atoms



Activity 1. Local survey of useful metals

- 1 Try to find the names of metals and alloys used in PNG. Draw a table as shown below and list beside each metal or alloy the composition and the uses and properties.

Name of metal or alloy	Composition	Use and properties
Example: Copper	100% Cu element	Electrical wiring (good conductor of electricity) Plumbing (corrosion resistant)

- 2 Where do some of these metals come from?
3 Draw a table like the one below to summarise your findings.

Metal	Natural occurrence	Extraction/ purification

Some important metals

Metals are obtained from ores that have to be mined. Town dwellers use many metals in everyday life whereas villagers use very few. Can you think of any metals that are used in both the town and the village? The adoption of *Western* life styles has changed Solomon Islander dependence on these metals. In many developed nations metals are essential to everyday living. Without them many people would not know how to survive.

Lead

Lead is mined extensively as a mineral called *galena* that is the compound lead sulfide (PbS). This mineral is usually found with *sphalerite*, zinc sulfide (ZnS). Therefore most lead mines are also zinc and silver mines. For example, Broken Hill in Australia, is a world famous silver-lead-zinc mine. This mine is a very large underground mine. The sulfides are separated from the ore after crushing to a fine powder. Roasting of the sulfides converts them to oxides. The oxides are then reduced using coke which is a form of carbon obtained from coal. In the following activity you will try to separate lead metal from its ore mineral, galena.

Lead does not occur naturally as a native metal. Why?



Research

1. Look up library references to find out how lead is processed.
 2. Try to find the uses of lead in PNG.
 3. What environmental concerns are there for using lead and lead compounds?
-

Aluminium

Aluminium is truly a more recent metal to be utilised by humankind. In 1880 aluminium cost almost one million Kina 00 per tonne due to the cost of producing it. In 1910 after the discovery of the Hall-Heroult process its price plummeted to less than K400 per tonne. Aluminium is the most abundant metal in the earth's crust (8%) occurring in many silicate minerals such as clay and feldspars. With the huge world demand, Australia produces in excess of 5 million tonnes of the metal per year.

Chemical Symbol:	Al
Atomic Number:	13
Atomic Weight:	27

Aluminium is a Group 3 element in the Periodic Table. It therefore has three bonding electrons available in the outer shells. When the element is oxidised, aluminium forms the Al^{3+} ion due to the loss of three electrons. Aluminium is a strong reducing agent that means it is a very reactive metal being more reactive than zinc and iron in the reactivity series. However some observed chemical properties of the metal do not reflect this reactivity. *Why?*



Figure 4. A World War II plane wreckage. The aluminium has withstood the effects of weathering as it does not react very well with air.



Activity 2

Properties of aluminium

After World War II there was a lot of scrap aluminium readily available around PNG. Where did villagers get the aluminium? Another good source of aluminium metal is the soft drink can. These can easily be cut with scissors but be careful not to cut your fingers!

In the following experiments you will attempt to determine the physical and chemical properties of aluminium.

For these tests use pieces of aluminium from drink cans or off-cuts from an aluminium window frame workshop.

Physical properties of aluminium

Test 1. Appearance of Aluminium

1. Obtain two strips of aluminium metal. Leave one strip dull and polish one with a piece of fine wet and dry paper. Compare the surfaces of the two strips.
2. Leave the two strips exposed to the air for a few days and again compare the surfaces. What do you notice? Why?

Test 2. Ductility and Malleability of Aluminium

1. Obtain some aluminium wire.

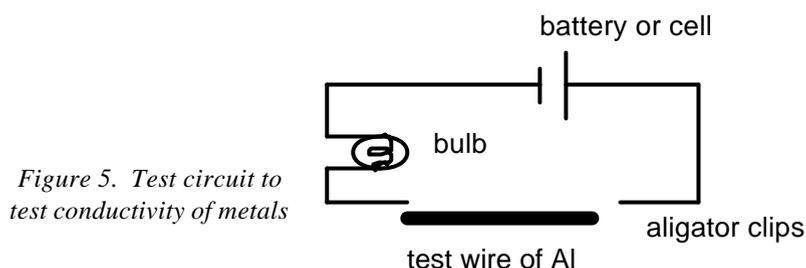
What does the existence of aluminium as wire tell you about the ability of aluminium to be drawn into a wire?

2. Place one of the strips of aluminium on a solid steel surface and try to hammer it flatter.

What happens?

Test 3. Conductivity of Aluminium

1. Test the conductivity of heat by holding one end of a strip of aluminium in a flame for only 2 seconds while holding the other end with your bare fingers. Remove the metal strip from the flame and describe what happens.
1. Use a test circuit with a bulb or a multimeter to test the electrical conductivity of an aluminium wire. Set up the test circuit as shown in figure 5



3. First connect the aligator clips to each other and see how bright the bulb is then connect the two aligator clips to the ends of the aluminium wire.

How does the brightness compare?

Chemical properties of aluminium

Test 4. Effect of Heating Aluminium in Air (oxygen).

1. Use tongs to hold a polished strip of aluminium in the bunsen burner for about 10 seconds.

Remove the aluminium and note how its appearance changes as it cools.

2. Continue heating the strip in the very hot part of the flame.

Does the aluminium melt or start burning?

Test 5. Reaction of Aluminium with Acids

(a) Reaction with cold dilute acids:

1. Place about 2cm of each of the dilute acids, HCl and H₂SO₄, into three test tubes in a test tube rack. Slowly slide a dull strip of aluminium into each. Observe what happens. Test for hydrogen gas by collecting the gas in an inverted test tube over the reaction tube and then slowly move the tube, still upside down, over the top of the bunsen flame.

Safety note: Make sure you do not point the test tube towards anyone while heating it.

2. Repeat the tests with polished strips of aluminium.

(b) **Reaction with hot dilute acids:**

1. Test dull and polished aluminium strips with hot dilute acids by warming each test tube carefully to see if the reactions go any better. Test for gases again.

Describe what happens.

Test 6. Reaction of Aluminium with Bases

1. Add pieces of "Alfoil" to a strong solution of sodium hydroxide (caustic soda) in a test tube. Observe the reaction in cold solution and then gently warm if necessary. Test the gas given off.

WARNING: Acids are very corrosive and you must not do this experiment without safety goggles. Do not point the test tubes towards anyone.

Importance of aluminium

Aluminium is the most abundant metal in the earth's crust accounting for 8% of the crustal composition. It is one of the main elements in most of the rock forming minerals called aluminosilicates (composed of Al, Si and O). The most economical mineral occurrence of aluminium is *bauxite* which occurs as rounded nodules in the soils of areas of extremes of wet and dry seasons such as Weipa, Australia. The Weipa occurrence is the largest single mine for bauxite in the world. Australia produces sufficient ore to extract 10 million tonnes of Al annually. Bauxite also occurs in some Pacific islands where volcanic ash and limestone has weathered, e.g. Solomon Islands and Caledonia.

Bauxite consists of 35% to 65% of alumina (aluminium oxide) as the minerals gibbsite ($Al_2O_3 \cdot 3H_2O$), boehmite ($Al_2O_3 \cdot H_2O$) and diaspore ($Al_2O_3 \cdot 2H_2O$). The other major component is iron oxide with some silicon dioxide.

Uses of aluminium

Cooking utensils and alfoil

Aluminium is used as a metal for cooking utensils and alfoil due to its good heat conducting properties and ability to be shaped easily.

Reflectors

Most mirrors are no longer silvered glass but glass with a thin aluminium film that has been deposited from a gaseous state. Telescope mirrors are always coated with aluminium. Reflecting blankets and fire retardant suits are coated with a film of aluminium. "Sisalation" used in the roof of a house for insulation from heat is also a type of aluminium foil.

Power lines

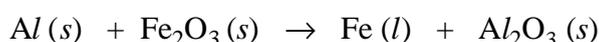
The high tension power lines are aluminium with a steel core. It is as good a conductor as copper and cheaper but needs the iron core to give it tensile strength. The resulting power lines weigh less and needs less pylons.

Alloys

Aluminium can be alloyed with copper, zinc or magnesium to form duralium (5% copper), zincalium and mag alloy respectively. The duralium has the strength of mild steel but has a low density and is used in aircraft construction. Zincalium is corrosion resistant and is replacing galvanised iron as a roofing and guttering material. Mag wheels are made from cast aluminium and magnesium alloy that is brittle but very strong.

Thermite reaction

The thermite reaction (Goldschmidt's process) enables welding of steel railway lines in remote locations. *Al* is a powerful reducing agent. When mixed, in the correct proportions, with powdered iron oxide and ignited the resulting temperature is so high that the iron oxide is reduced to molten iron which fuses the cracked rails together.



Copper

Copper has been used for ornaments, tools and weapons for more than 6000 years. Like gold copper does occur in native form, i.e., in the elemental form. Copper is relatively unreactive compared to elements such as aluminium, zinc and iron. *Native copper* occurs in oxidised parts of copper ore bodies. *Why?* Copper is one of the most useful non-ferrous metals. More than half of the world production is used for electrical wiring and plumbing.

Copper mines, such as those in OK Tedi and Mt Isa (Australia), obtain copper from the sulfide ore minerals, *chalcopyrite* (CuFeS_2) or *bornite* (Cu_5FeS_4). The ore is mined, crushed and the sulfides are separated by froth flotation. A mineral oil and detergent mixture is frothed with air and the sulfide particles float on the bubbles. The sulfides are concentrated and are then sent to the smelting plant where they are first roasted and then reduced to produce the copper metal. However the copper is not pure and needs to be sent to another place to be electrolytically purified, e.g., blister copper from Mt Isa is sent to Townsville in Queensland, Australia, to be turned into very pure copper sheets.

Iron and steel

If you look at different pieces of iron and steel they differ in a number of ways.



Activity 3 Comparing Steels

1. Compare stainless steel to mild steel. What is the difference?
2. Why do we need different types of steel? What special properties do different steels have?
3. Do you think iron could be found in its elemental form? Why?



Figure 6. This World War 2 ammunition magazine made from high grade stainless steel. It has not rusted after almost 60 years.

Pure iron does not corrode readily whereas steel does. This is because steel is an alloy of iron and other metals. These other metal atoms and iron atoms act like the terminals of small cells producing electricity. The iron is generally more reactive so it oxidises to iron oxides (rust). Iron and steel production is the largest chemical industry in the world. Steel alloys have become the most important structural material today. Steel's hardness makes it useful for many applications such as bridges, car bodies, ships, reinforcing, building frames, nails and screws.

Production of iron

The main minerals of iron ore are hematite (Fe_2O_3) and limonite ($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$). The ore is mined in large opencut mines in Western Australia and shipped to Australian steel mills or to overseas markets for the production of iron. The **blast furnace** is used to convert the iron oxides into iron metal. The crushed iron ore is mixed with coke and limestone and fed into the top of a tall furnace. Hot air is pumped through the furnace. The mixture reaches 1900°C and the molten iron accumulates at the bottom. The molten iron is tapped from the bottom of the furnace. This **pig iron** contains about 96% iron and 4% carbon. More carbon is removed by further aeration. The resulting form of iron is often used for casting and is called **cast iron**.

Alloys of iron

The addition of other elements to iron produces steel. The most commonly used steel is **mild steel** which is used in car bodies, wire, nails, pipes, nuts and bolts. **Hard steel** is used for drill bits, knives and chisels contain 0.6 to 1.5% carbon as well as traces of other special elements such as tungsten and manganese. **Medium steels** are used for girders and beams and these contain 0.3 to 0.6% carbon as well as

molybdenum. **Stainless steel** contains varying amounts of *chromium* and *nickel* as well as other minor elements. For example, a typical stainless steel could be 74% iron, 18% chromium and 8% nickel. Stainless steels are given numbers, e.g., 420, 316, which tell us the alloy composition and the resistance to corrosion. Marine use requires high grade stainless steels such as alloy number **316**.

Tempering of steel

Steel is used for many different purposes. Each use requires different properties. One of the useful properties of metals is that the crystal structure can change with different compositions, cooling rates and quenching temperatures.

Steel tools often need sharpening or reshaping. Grinding and filing can return the sharpness of a point or blade but the steel often becomes blunt quickly. This is because the steel has “lost its temper”. This doesn’t mean it has an attitude or is mad with someone! It means that the desired crystal structure is no longer the same as that needed. To change the crystal structure back we need to temper the steel. This is easily done with a very hot fire with many coals. When steel is heated in such a fire the steel glows red hot. If we now cool it from the cherry red colour we can stop the crystal structure at a point that will give us the property needed. The colours, matching temperatures for quenching and the uses of each tempered steel is given below in Table 2.

Table 2 Comparison of colour, temperature and uses of tempered steel

Colour	Temperature °C for quenching	Use of tempered steel
Bright blue	310	Spring steel
Medium blue	299	Knives, saws and chisels
Dark blue	288	Cold chisels, picks and mattocks
Purple	282	Scissors, tin snips, shears
Bronze	271	Hammers and drills
Brownish yellow	249	Wood chisels and engravers,
Dark yellow	246	
Straw yellow	221 - 232	Punches and chasing tools
Pale straw	199 - 204	Taps
No colour	<94	Scrapers



Activity 4 Tempering a steel spring

Materials

- Small steel spring, knife or pick
- Bunsen burner or hot fire with coals

Procedure

1. File or grind the working point or edge until sharp.
2. Heat the working point in the coals or bunsen until cherry red.
3. Remove from fire or bunsen and carefully watch the changing colour at the working point.
4. When the colour is bright blue (spring) or medium blue (for knives and picks) plunge the object into a large volume of water or waste oil.
5. Test your tempered object to ensure that it keeps its edge. If not you will have to repeat the process.



Research

Use the library to try to find the conditions and temperatures needed to anneal or temper other metals and alloys, eg. hardened copper.

More reactions of metals

Alloys contain two or more different metals. Some metals are more reactive than others. This causes electrical currents to flow when alloys are placed into conducting solutions such as sea water. These natural cells are called voltaic cells. The iron in stainless steel is more reactive than nickel therefore it is possible for the iron to form iron oxides (rust). Therefore a combination of metals is needed that will prevent the electric cell from starting.

Steel rusts but pure 100% iron does not. Why?

You should already know something about the reactivity of metals such as sodium and calcium. You would also realise that gold is very unreactive. *What about all the other metals?*

The ease of giving up electrons is a good guide to how reactive metals are. This is called electron affinity. The lower the figure the more reactive is the metal.



Activity 5. Exchanging metals

Some solutions of salts are poisonous if they are swallowed. You should ensure that you carry out your experiments in a safe location and either dispose of the solutions when your experiments are complete or label them and store them in a safe place.

Materials

- two clear glass containers
- copper sulfate
- clean iron nails
- zinc metal from a torch battery

Procedure

1. Make up 50 mL solutions of copper sulfate in water in two glass containers. Add sufficient copper sulfate to each until the colour is clearly blue (~1 heaped teaspoon).
2. To one container add some shiny iron nails and to the other add some small shiny pieces of zinc metal. Notice the change in colour of the solution and any precipitate that forms when the solutions are allowed to stand for several hours.
3. When the reactions are complete, add some iron nails to the solution containing the zinc and some shiny zinc to the solution containing the iron nails. Notice any further reactions that take place.
4. Try other metals in the place of iron or zinc (for example, lead, aluminium, nickel).
5. Keep the solutions you have prepared. You can use them in other experiments. Be sure to label them carefully and store them in a safe place.

Questions

- 1 Write word equations for each reaction that occurs.
- 2 Arrange the metals in the order of reactivity starting with the most reactive one.

Corrosion of metals and cells

What makes metals disappear or change before our eyes? How can we stop this happening?

Metal corrosion costs industries and individuals billions of dollars annually. We see the aluminium on outboard motors changing to a white crumbly powder. We see steel ships rusting. Motor cars slowly rust away.

Whenever we put a metal into a moist environment corrosion begins. The rate of corrosion depends on many factors but an electrical circuit is needed. This can be provided by seawater.

The salt water forms a connection between different parts of the same metal or between different metals and conducts electrical current. For some metals, oxygen is also needed. If we look at a steel shipwreck near a shore, the part at or near the surface rusts quickly while the parts in deeper water rust very slowly. In fact steel wrecks on the bottom in deep water have little rust because very little oxygen is present.

Reactivity of metals

Reactions occur between different metals in solutions of salts. These reactions are also corrosion reactions. The more active metal goes into solution while the less active deposits out of solution as a solid metal. These reactions are called electrochemical reactions. Electrons are transferred from a metal to other ions or molecules. In doing so an electric current is created. The voltage can be measured using electrodes. The negative electrode is where the metal is oxidised. The positive electrode is the one where the electrons are accepted. In fact not all of these reactions are destructive. All of our cells and batteries depend on this type of reaction. You have already looked at the dry cell and should realise that the negative electrode of that cell is the zinc casing which gradually disappears as it turns into Zn^{2+} ions. We can experiment with combinations of different metals in different solutions and pastes to get different voltages. Some cells like those in the lead acid accumulator (car battery) produce just over 2 volts. The dry cell only produces 1.6 volts (rated at 1.5 volts).



Activity 6 Which metals corrode faster?

- 1 Obtain a beaker of sea water.
- 2 Arrange strips or wires of different metals around the edge of the beaker. Make sure none touch.
- 3 When you set up the experiment measure the voltage between every possible pair of metals.

- 4 *Predict which metals will corrode faster.*
- 5 *After a few days note the appearance of each metal.*
- 6 *Compare your observations to your predictions.*



Research

- 1 *Find out how steel ships are protected from corrosion.*
- 2 *What alloy are outboard motors made of? How is this alloy protected from corrosion in the ocean?*
- 3 *What is done to protect aluminium frames from corrosion?*
- 4 *How can rust be prevented in motor vehicles?*

Toxicity of metals

Some metals and metal ions are of a concern when they are released into our environment. Only very small amounts of some metals are extremely toxic to living organisms, for example, mercury salts. Generally it is the compounds of metals that are of the greatest concern because soluble ions can easily enter the environment and ultimately into the tissue of organisms. Sometimes the effect isn't seen for many years as the metal ions accumulate in the body tissue such as that of the liver in humans. When the concentration reaches a certain level the effect is devastating and can be fatal. The saying, "Mad as a hatter", originated from the description of hat makers in Europe who used mercury salts to shape the hats from felt. The result is that many hatters ended up insane! However the same metal is used to make amalgam to fill your teeth but is very safe as the mercury doesn't dissolve in any appreciable amount.

A Standard for allowable limits of toxic metals in ceramic cooking utensils states that large casserole cooking pots must not contain more than 2 mg/kg lead and 0.2 mg/kg cadmium while for small casseroles the figures are 7 mg/kg lead and 0.7 mg/kg cadmium. For plates the figures are 20 mg/kg lead and 2.0 mg/kg cadmium. We can test for lead in ceramics however most reputable pottery manufacturers do not use lead glazes. (The cadmium is an impurity in the lead). Lead dioxide was used as a base for oil based paints for many years. This led to a lot of lead poisoning of children who used to get the powdered paint on their hands and then digest the powder with food (didn't wash their hands!).

Note: The mg/kg is the same unit as parts per million (ppm). Therefore 2mg/kg is the same as 2 grams in 1 000 000 grams or 2 grams in 1 tonne! Not much!

Recently many countries have begun to phase out the use of leaded (super) petrol as a fuel for vehicles due to world findings which show a relationship between lead poisoning in the populace that lives in or

near high traffic areas. The problem is due to the anti-knock additive lead tetraethyl, $\text{Pb}(\text{C}_2\text{H}_5)_4$.

Recycling of metals

As we keep using metals we are depleting a non-renewable resource. As a society we cannot keep removing metals from the ground, using them and then throwing them away. Many countries now have recycling programs where wastes that can be reused are collected separately by the refuse service. One of the most effective ways of ensuring people recycle containers is to place a deposit on them at the point of purchase or offer an attractive price for the waste product, for example, aluminium cans. In most countries scrap aluminium sells for about Kina 2.00 per kilogram.

Plastic bottles are also recycled in large quantities. However the cost of recycling plastics is generally more than the cost of making the new plastic. One way to make recycling more attractive is to put a tax on all plastic products. This tax should be used solely for research into recycling and to offset the costs of recycling by companies.

Unfortunately many world governments redirect taxes to other areas therefore most voters are against further taxes. A more workable solution may be to only allow the sale of plastics by companies who actively recycle and accept responsibility. It will mean that the price of plastics will need to increase to absorb the extra costs.

When metals are recycled they can either be melted and turned into pure ingots ready for further milling or they can be chemically dissolved and converted to useable salts.

2. Useful non-metals

Non metals are those elements that do not exhibit metallic properties. All gaseous elements are naturally non-metals. Generally elements in Groups 4,5, 6, 7 and 8 are non-metals. The solids of these groups of elements are generally dull in lustre and do not conduct heat or electricity. Non-metals generally have lower melting and boiling points than metals. There are some exceptions in Group 4 such as silicon (Si). When non-metals react with each other they generally form covalent bonds. These are electron-sharing bonds. However many of these elements react with metals to form ionic bonds. Ionic bonds are due to the transfer of electrons between atoms.

Acids and bases

A number of non-metals are the basic building block of many common and very useful acids and bases.

<i>Chlorine</i>	<i>Hydrochloric acid</i>	<i>HCl</i>	<i>Spirits of salts</i>
<i>Fluorine</i>	<i>Hydrofluoric acid</i>	<i>HF</i>	<i>Glass etching</i>
<i>Sulfur</i>	<i>Sulfuric acid</i>	<i>H₂SO₄</i>	<i>Car battery acid</i>
<i>Nitrogen</i>	<i>Nitric acid</i>	<i>HNO₃</i>	<i>Cleaning metals</i>
<i>Nitrogen</i>	<i>Ammonia</i>	<i>NH₃</i>	<i>A powerful cleaning agent in solution</i>



Research

- 1 What is pH?
- 2 What is meant by the term **1 Molar** solution?
- 3 Use Universal indicator to find the pH of a 1 Molar solution supplied by your lecturer.



Activity 7. pH of common acids and bases

In this experiment you will investigate a number of commonly used substances for their acidic and basic properties. The substances used for the experiment are used in your home or garden. You should take care in handling all of these substances as the risk of injury is always present.

Materials needed:

- Spot plate
- Litmus paper
- pH paper
- Universal indicator solution
- Samples of local substances as provided.

You should test samples from the following list.

- Cleaning: cloudy ammonia, chlorine bleach (White Magic), oxygen bleach (Nappysan), washing soda, borax, washing powders, detergents, soaps and shampoos.
- Cooking: vinegar, lime juice, cream of tartar, baking soda.
- Drinks: Water, tonic water, soda water, Coca Cola and carbonated water
- Medicines: Milk of magnesia
- Fertilisers: Sulfate of ammonia, superphosphate and sulfur.
- Water samples: Sea water, rain water, town water, river water, stagnant water

Procedure:

1. Obtain labelled samples from the bench.
2. Place a few drops of each sample on the spot plate.
3. Test each sample with indicator papers. Record your results in a table.
4. Add one to two drops of *Universal Indicator* to each sample and record the pH.

Questions:

1. Any substance with a pH less than 3 or greater than 10 may be considered potentially harmful if swallowed. List the substances, using the groups' results, that might be dangerous.
2. Now look at the original packaging for the substances and check the contents and the warning on the label. Is there a warning? Should there be a warning?
3. How could substances of pH less than 3 and greater than 10 be harmful if swallowed?

Ammonia

One of the most important compounds to humankind is ammonia. Throughout history ammonia and other nitrogen compounds have been used as a natural fertilizer in the form of animal and human wastes. The characteristic odour of urine and animal droppings is due to ammonia gas. Early civilisations realised the importance of the components of excrement as a fertilizer. In fact cropping practices in many Pacific Island countries rely on the natural release of ammonia and nitrogen compounds from rotting forest litter. Pacific cultures rarely use synthetic fertilizers to grow staple foods. Nutrient is quickly used up in the *gardens*. This is why new gardens need to be continually cleared in the forest.

An ammonia molecule is composed of one atom of nitrogen and three atoms of hydrogen which are covalently bonded. The structure of the

molecule is such that there is a pair of unshared electrons on one corner of a four cornered pyramid. The other three corners are occupied by the three hydrogen atoms. This makes the ammonia molecule very polar. That is the molecule behaves as though it has negatively and positively charged ends. As a result the ammonia molecule is capable of attaching to other charged particles and polar molecules. This property makes ammonia a great cleaning agent.



Research about ammonia

1. Find the names of common chemicals that contain ammonia. List these.
2. Ammonia is also a very important substance in the natural nitrogen cycle. Look up some books to find out more about ammonia's importance. Illustrate and label the ammonia cycle.

The following experiments will enable you to investigate some of the common physical and chemical properties of ammonia.



Activity & Properties of ammonia

Physical Properties of ammonia

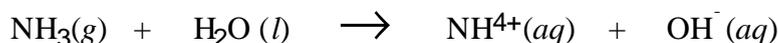
Test the odour by gently wafting a hand across the top of a bottle of household ammonia or cleaner that contains ammonia.

1. What does ammonia smell like?

Chemical properties

Reactions of ammonia as a base.

Ammonia forms an alkaline solution due to the equilibrium reaction between the ammonia and water molecules. The reaction is as follows:



Ammonia forms NH_4^+ ions in water due to the ammonia molecule accepting a proton (H^+) from the H_2O molecule. This leaves the solution alkaline due to the formation of OH^- ions. However it only forms a weak base in solution due to a small amount of the ammonia molecules reacting with the water molecules.

Many of the reactions of ammonia are really due to the very polar molecule. With strong acids ammonia forms ammonium salts by accepting a proton from the acid. This gives rise to many important commercially used salts of ammonia as shown in Table 2.2.

Table 2.2 Salts formed by reaction of ammonia with various acids

ACID	SALT FORMED	USE OF SALT
HCl	NH ₄ Cl	Dry cells; sal ammoniac
HNO ₃	NH ₄ NO ₃	Explosives; fertiliser
H ₂ SO ₄	(NH ₄) ₂ SO ₄	Fertiliser
H ₃ PO ₄	NH ₄ H ₂ PO ₄	MAP Fertiliser
	(NH ₄) ₂ HPO ₄	DAP Fertiliser

Precipitation Reactions with ammonia solution

Ammonia solution acts as a base in precipitating hydroxides with many metal salts however some don't appear to behave the same way.

1. Obtain solutions of silver nitrate, copper nitrate, zinc chloride and aluminium chloride.
2. Place about 5mL of each in four separate test tubes.
3. Use a dropper to slowly add 6 molar ammonia solution to each tube. Agitate the contents after adding the ammonia each time.
4. *Observe what happens? Complete the table below:*

Table 2.3 Reactions of ammonia solution with different metal ions

Metal ion	Observation	Reaction
Al ³⁺		
Zn ²⁺		
Cu ²⁺		
Ag ⁺		

Importance of ammonia

Uses of ammonia

Structure of the ammonia molecule

Electronic Configuration of nitrogen is such that it has five bonding electrons, of which three can form shared pairs with hydrogen atoms. This leaves an unshared pair of electrons which form a larger orbital that repels the other three. This results in a molecule which is pyramidal and very polar, that is, negative at the unshared electron end and positive at the side the hydrogen atoms are on.

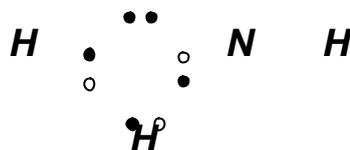


Figure 7. Dot diagram of bonding in ammonia

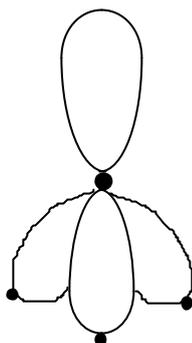
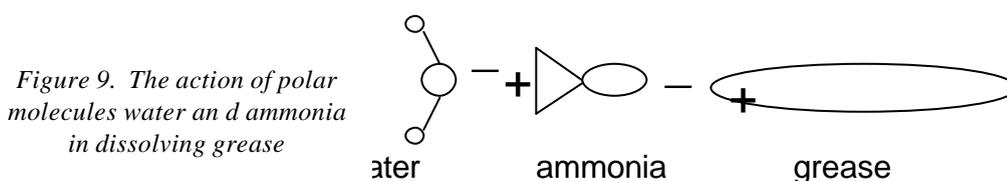


Figure 8. Orbital diagram of bonding in ammonia

Use in cleaners

The polarity of the ammonia molecule makes it attach readily to other polar molecules such as water and many hydrocarbons or organic molecules. This effectively means that ammonia solutions in water can literally dissolve grease. Due to the linking of the ammonia molecule with a water molecule at one end and a grease one at the other thus the grease can be carried off in the water. Ammonia is used in many cleaning agents such as *Cloudy Ammonia* (the cheapest and most concentrated form of ammonia in water) and *Handy Andy* (a mixture of detergent and ammonia).



Refrigeration

Ammonia gas is easily compressed to a liquid and as it is allowed to evaporate or "boil" it absorbs heat from the surroundings thus giving a cooling effect.

In a refrigerator the ammonia is stored in a sealed pressure tank and is allowed to boil in the freezing compartment of a refrigerator. This cools the freezing compartment to below 0°C . The warm gas then passes through the external tubes at the back of the refrigerator and loses some of the heat. It is then recompressed and stored in the

storage tank. This cycle repeats itself whenever the thermostat activates the motor and valves on the cooling side.

These days domestic fridges use organic gases such as freon which are more efficient, however, due to the cheapness of ammonia, many large commercial refrigeration units still use ammonia, e.g., ice works.

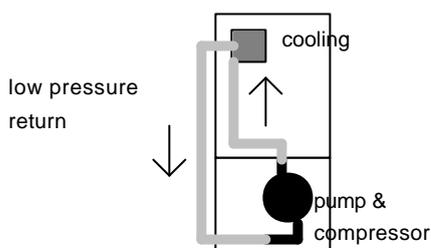


Figure 10. Schematic diagram of the refrigeration cycle

Fertilisers

Ammonia is a very important economic chemical as it is used to synthesise a large number of other chemical substances including fertilisers. Ammonia, itself is a rich source of nitrogen. Ammonia is also used to make a number of other fertilisers. The solid products are generally easier to handle in smaller quantities. Some very large farms have tankers deliver anhydrous ammonia or aqueous ammonia in bulk. Smaller farms find it easier and more economical to buy 1 tonne or 50kg bags of urea as the principal source of nitrogen. Other compounds contain other elements beneficial to plants. Nitrogen fertilisers contribute directly to over \$6 billion worth of grain, sugar, cotton, rice and fibre production as well as mining products (explosives) in Australia.

Anhydrous ammonia is liquefied ammonia gas, which contains 82% nitrogen.

Aqueous ammonia is ammonia solution in water and contains 20.5% nitrogen..

Table 2.5 Composition of other nitrogen fertilisers

NH₃ reacted with:	produces:	%N	%P
CO ₂	Urea	46.0	
HNO ₃	Ammonium nitrate	34.0	
H ₂ SO ₄	Sulfate of ammonia	20.5	
H ₃ PO ₄	DAP diammonium hydrogen phosphate	19.0	20.0
	MAP mono ammonium dihydrogen phosphate	13.0	22.0

3. Useful organic substances

There are many natural organic compounds which have been used by human civilisation for a variety of reasons: dyeing fabrics, medicines and drugs, ink, fuels, plastics, synthetic fibres, glues and food.

- 1 *Try to list the natural plants of PNG and their medicinal uses.*
- 2 *Do you think they work?*
- 3 *Many natural dyes are known to humankind. List some of the plants or minerals which provide colour pigments in PNG.*



Activity 9. Preparation of black ink

For many centuries humankind has used inks for writing. In the following experiment you will try to make some black ink. Ferric tannate is the basic ingredient of black inks. Tannic acid is a natural organic acid that occurs in many plants including Acacias and tea. In this experiment tea leaves will be used as the source of tannic acid.

Materials

- Tea bags, saucepan, two glass jars, a pad of steel wool, a small quantity (100 mL) of vinegar, about 1 mL of a 3% hydrogen peroxide solution, filter funnel, cotton wool

Procedure

1. Prepare a solution containing tannic acid by adding boiling water to fresh tea leaves or a tea bag. Make the solution equivalent in concentration to strong black tea. One cup of solution will be sufficient.
2. To prepare a solution containing iron (III), boil a small quantity (~100 mL) of vinegar to which a pad of steel wool has been added (the steel wool should not contain any soap). Allow the solution to simmer for 5 to 10 minutes, and then strain the solution through a filter funnel containing a loosely fitting plug of cotton wool
3. When the solution is cool, add about 1 mL of hydrogen peroxide solution. The colour of the solution should now be a dark brownish-red, indicating the presence of iron (III).
4. To produce ferric tannate add a quantity of your tannic acid solution (say 10 mL) to a roughly equal amount of your solution of ferric ion. The solution should turn black as a result of ferric tannate being produced. Ferric tannate is the major ingredient of many black inks.
5. Now you might like to experiment making an ink using varying amounts of your ferric tannate solution and glycerine. Try writing with your ink! You might even need to fashion a nib out of a large chicken feather or split bamboo.

Fabrics and flammability

The large sheets of butcher's paper that are often used for children's paintings can be a fire hazard. Paper can be rendered non-flammable by soaking it in **alum**, $\text{K}_2\text{SO}_4\text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$. The protection afforded by the alum can be simply demonstrated in this experiment.



Activity 10 **Invisible writing!**

- 1 Write on paper with alum solution and allow it to dry
- 2 Heat the paper carefully (over a fire) but do not touch the flames.
- 3 Describe what happens. Why does this happen?

However, high retention of flame-retardant properties on washing and dry-cleaning is nowadays required of flame-retardant treatments. The serious nature of clothing fires was aptly summed up in a National Bureau of Standards (1973) report: "If your house catches fire you will probably escape with your life and your skin. If your pyjamas catch fire you will probably lose your skin and possibly your life."

Plastics

Plastics are one of the wonders of the World. They are also a problem due to the environmental damage that can be done by inappropriate disposal of old plastic products.

Do we depend on plastics too much?

Polymers

Molecules that are capable of joining together to form very large molecules are called **monomers**. The substances produced by forcing the molecules together are **polymers**.

Polymers may be moulded or shaped, usually by the application of heat and pressure. Other special properties of polymers include low density, low electrical conductivity, transparency and toughness.

These properties make plastics useful for a great variety of products.

These include tough and lightweight drink bottles made of **polyethylene terephthalate**, flexible garden hoses made of **polyvinyl chloride**, insulating food containers made of foamed **polystyrene**, shatterproof windows made of **polymethyl methacrylate**.



Activity 11. **Many different plastics**

- 1 Collect samples of different plastics used for food packaging and general industry. (Hint: There are a lot of plastic parts on cars!)
- 2 Arrange the plastics together that appear to have similar properties.

- 3 Research or read the information in your booklet to complete a table summarising the uses of these plastics.

Plastic type	Density	Toughness	Hardness	Uses
--------------	---------	-----------	----------	------

- 4 Test the flammability of your samples. Describe the products of combustion.
- 5 What environmental problems do plastics create?

Some plastics

Methyl methacrylate

Methyl methacrylate is polymerised using the organic group shown. Methyl methacrylate can be in the form of moulded sheets is used for domed skylights, swimming pool enclosures, aircraft canopies, instrument panels, and applications the plastic is sold in the form of thermoformed, but it is also injection-moulded for taillights and lighting-fixture covers.

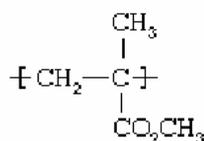


Figure. Free radical used to produce the polymer - Methyl methacrylate (Source: Encyclopaedia Britannica 2001)



Activity 12 Alternatives to plastics

1. Draw two columns headed **plastic object** and **alternative to plastic**. List all the plastic objects you can think of. Beside each, list an alternative natural product if there is one.
2. Now try to list the types of plastics and their uses in PNG.
3. List some of the problems plastics cause in our environment. Suggest ways to reduce this problem.

The following tests on plastics give you some insight into the different properties, good and bad, of everyday plastics.

Materials

Samples of plastics
Copper wire in a cork holder
Large beaker with water
Spatulas

Procedure

Safety message: When burning plastics:

- Use very small pieces of your samples and hold them with tongs or a wooden peg.

- Experiment in a well ventilated place because of the fumes produced
- Hold the burner or candle at an angle so that any drops of molten plastic fall onto an asbestos or other non-flammable mat..

1. Copper wire test:

Heat a copper wire (stuck into a cork as a holder) in a gas flame until any yellow or green colour disappears. Press the heated wire into the plastic sample and then put the wire with a little molten plastic on it back into the flame. A green colour indicates that the plastic contains halogen—probably chlorine in poly (vinyl chloride) (PVC) or poly (vinylidene chloride) (PVDC). Before repeating the test with another plastic, again heat the copper wire until the green colour disappears.

It should be noted that an additive may contain a halogen (chlorine, bromine or iodine) that gives rise to a positive result. Also cyanide (from, say, Orlon) may give a positive result.

2. Density:

Some polymers are less dense than water and hence will float. These are polyethylene, polypropylene, styrene-butadiene and nitrile (some types). It is essential for the sample (not a foam type) to be properly wetted and pushed below the surface, and then released. The presence of large amounts of additives can change the density.

3. Feel

Poly(ethylene) and poly(tetrafluoroethylene) have a waxy feel not possessed by other polymers. Clean the surface to remove grease or plasticisers.

4. Heating tests (outdoors)

A small piece (0.1 g) of the material is placed on a clean spatula (nickel spoon-like object), previously heated to remove traces of combustible material. It is then gently warmed, without ignition, over a small colourless gas flame until it begins to fume. The sample is removed from the flame and the fumes are tested with moist litmus paper (red and blue) to determine whether they are acidic, alkaline, or neutral. Check the odour as well. The sample is now moved to the hottest zone of the small gas flame and the following points noted in a table:

- 1 *Whether or not the material burns and if so, how easily.*
 - 2 *The nature and colour of any flame (very sooty flame generally indicates an aromatic polymer, but may result from carbon black filler).*
 - 3 *Whether or not the material continues to burn after removal from the flame.*
 - 4 *The nature of any residue.*
-

Glues and adhesives

Glues have been used as early as 3000 BC in wooden furniture construction in Egypt. Original glues were a gelatine-like adhesive substance extracted from animal tissue, particularly hides and bones, or from fish, casein (milk solids) or vegetables.

What natural glues are used in PNG? Discuss this in class.

Synthetic resin adhesives such as the epoxies are replacing **glue** for many uses, but **glue** is still widely used as an adhesive in woodworking, in the manufacture of such abrasives as sandpaper, and as a colloid in industrial processes; *e.g.*, the recovery of solid particles suspended in a liquid.

Natural glues

Natural glues are primarily of animal or vegetable origin. Though the demand for natural products has declined since the mid-20th century, certain of them continue to be used with wood and paper products, particularly in corrugated board, envelopes, bottle labels, book bindings, cartons, furniture and laminated film and foils. Owing to various environmental regulations, natural adhesives derived from renewable resources are receiving renewed attention.

Casein glues

This glue is made by dissolving casein, a protein obtained from milk, in an aqueous alkaline solvent. The degree and type of alkali influences product behaviour. In wood bonding, casein glues generally are superior to true animal glues in moisture resistance and aging characteristics. Casein also is used to improve the adhering characteristics of paints and coatings.

Blood albumen glue

Glue of this type is made from serum albumen, a blood component obtainable from either fresh animal blood or dried soluble blood powder to which water has been added. Addition of alkali to albumen-water mixtures improves adhesive properties. A considerable quantity of **glue** products from blood is used in the plywood industry.

Starch and dextrin

Starch and dextrin are extracted from corn, wheat, potatoes or rice. They constitute the principal types of vegetable adhesives, which are soluble or dispersible in water and are obtained from plant sources throughout the world. Starch and dextrin glues are used in corrugated board and packaging and as a wallpaper adhesive.

Animal glue

The term animal **glue** is usually confined to glues prepared from collagen from mammals, the protein constituent of skin, bone and muscle. When treated with acids, alkalis or hot water, the collagen

slowly becomes soluble. If the original protein is pure and the conversion process is mild, the high-molecular-weight product is called **gelatine** and may be used for food or photographic products. The lower-molecular-weight material produced by more vigorous processing is normally less pure and darker in colour and is called **animal glue**.

Animal glue traditionally has been used in wood joining, book bindery, sandpaper manufacture, heavy gummed tapes, and similar applications. In spite of its advantage of high initial tack (stickiness), much animal **glue** has been modified or entirely replaced by synthetic adhesives.

Synthetic adhesives

Virtually all synthetic adhesives and some natural adhesives are composed of **polymers**, which are giant molecules formed by the linking of thousands of simpler molecules known as **monomers**. Polymers impart strength, flexibility and the ability to spread and interact on a surface.

There are six structural-adhesive families:

- **epoxies**, which exhibit high strength and good temperature and solvent resistance,
- **polyurethanes** which are flexible, have good peeling characteristics, and are resistant to shock and fatigue,
- **acrylics**, a versatile adhesive family that bonds to oily parts, cures quickly and has good overall properties,
- **anaerobics**, or surface-activated acrylics, which are good for bonding threaded metal parts and cylindrical shapes,
- **cyanoacrylates**, which bond quickly to plastic and rubber but have limited temperature and moisture resistance, and
- **silicones**, which are flexible, weather well out-of-doors, and provide good sealing properties.

Contact cements

Contact adhesives or cements are usually based on solvent solutions of neoprene. (They have a strong smell). They are so named because they are usually applied to both surfaces to be bonded. Following evaporation of the solvent, the two surfaces are joined to form a strong bond. Contact cements are used extensively in the assembly of automotive parts, furniture, leather goods (shoes) and laminated furniture. They are also effective in the bonding of plastics.

Epoxy resins

The formation of the polymer (a chemical reaction known as **polymerisation**) can occur during the **curing** of epoxy resins. There are many epoxy resins on the market. They usually come as a “two pack”, that is two containers or tubes. One contains the resin and other

the hardener. When mixed the reaction starts and polymerisation takes place simultaneously with adhesive-bond formation.).

Superglues (**cyanoacrylates**) set on exposure to air. You do not have to mix two parts together.

In some other adhesives the polymer is formed before the material is applied as an adhesive. It cures in the air. Many floor covering adhesives are of this type. There is only one container.

Fibreglass

Fibreglass actually refers to the glass filaments and yarns which add strength and electrical resistivity to moulded plastic products, such as boat hulls, automobile body parts and housings for a variety of electronic and electrical products. Glass fabrics are used as electrical insulators and as reinforcing belts in automobile tyres. Glass fibres are used to produce fibre glass cloth, which is commonly used in PNG to repair canoes. A two pack epoxy resin (fibre glass resin) is used to bond the cloth to the canoe.

Fibreglass wool is an excellent sound and thermal insulator. It is commonly used in buildings, appliances and plumbing. It is packed inside the lining of a refrigerator.



Activity 13 Common glues used in PNG

Work in groups to investigate and discuss the different glues used in PNG.

- 1 *Make a summary of the glues discussed in this module. Use the headings below.*
- 2 *Try to obtain some types of glue and use as directed.*
- 3 *Devise an experiment to test the strength of the bond formed.*

Adhesive	Natural/synthetic	Origin	Use	Strength
----------	-------------------	--------	-----	----------

Soap and detergents

Soaps and detergents are substances that, when dissolved in water, possess the ability to remove dirt, oils and grease from surfaces such as the human skin, textiles and other solids. These substances affect the surface of water and its ability to mix with other liquids and to dissolve oils and fats.

Soap

The manufacture of soaps and detergents is a very old industry dating back to at least the first century AD. Soaps are relatively easy to make and many households, in the 19th century, often made their own soap. You can also make soap from local oils such as coconut and palm by adding caustic soda. The reaction is called **saponification**.

 **Activity 14 Household soap**

In this activity you will:

- produce a sample of soap from fat or coconut oil.
- test the properties of your sample of soap.

What you will need

- 5 g of lard (cooking fat)
- 10 mL of coconut oil
- 10 mL of 95% ethanol
- 3 x 100 mL beaker
- 3 mL of 50 % NaOH solution (50 g NaOH in 50 mL water)
- 10 mL graduated cylinder
- 50 mL saturated NaCl solution
- stirring rod
- bunsen burner or heating source
- 40 mL acetone
- 10 cm length of soft wire (iron or copper)

DANGER: Do not use ethanol or acetone near any naked flames. Use a water bath.

1. Making the soap

1. Place 5 g of lard or oil into a 100 mL beaker.
2. Add 10 mL of 95% ethanol.
3. Gently warm the mixture in a water bath to melt the fat.
4. Slowly add 3 mL NaOH solution while continually stirring the mixture.
5. Allow to cool for 15 minutes.
6. Add 50 mL water and gently heat with stirring until the soap dissolves.
7. Add 50 mL of saturated salt solution to “salt out” the soap.
8. Cool the solution and the soap will float to the top.
9. Spoon out the soap with a spatula and place in a filter paper. Allow to drain.
10. Place the soap in a beaker and add a mixture of 20 mL water and 40 mL acetone. Break up the lumps and stir to thoroughly wash the soap.
11. Filter the soap again and remove from the filter paper into a suitable mould. Press into a cake.

2. Testing the soap

Lathering

- 1 Try to wash your hands with the soap using tank water. Dissolve half your soap into 50 mL of water.
- 2 Dip a wire ring into the solution and try to blow a soap bubble.
- 3 Describe the lathering of your soap.

If the soap is slippery it may contain too much residual NaOH. Wash your hands with vinegar to get rid of the slimy feeling.

Solubility

- 1 Put 6 drops of coconut oil into each of two test tubes.
- 2 Add 10 drops of water to one and 10 drops of your soap solution to the other.
- 3 Shake vigorously for 10 seconds.
- 4 Describe the effects of soap on the miscibility of oil in soapy water.

Effect of hard water on soaps

- 1 Collect different samples of water from the local area: bore, creek, se, river, pond, etc.
- 2 Pour 5 mL of your soap solution into each of three test tubes.
- 3 Add 5 mL of the water sample to each test tube and shake for about 10 seconds.
- 4 Record your observations.

Alkalinity

- 1 Add a drop of Universal Indicator to about 5 mL of your soap solution.
- 2 Is it neutral, acid or alkaline? What problems would you have if you use soap that is too alkaline?
- 3 Obtain commercial samples of soaps, local and imported, and dissolve small pieces in water and test these soaps for alkalinity.
- 4 How do they compare to your soap?
- 5 Are some of the commercial soaps too alkaline?
- 6 Record your observations.

Detergents

Repeat the above experiments using samples of commercial detergents. How do these compare to soaps?

Detergents

Detergents are a modern substance. These are made synthetically from oil and gas resources through a complex process. They contain various surface-active agents (surfactants) effective in dislodging foreign matter from soiled surfaces and retaining it in suspension.

Dishwashing and laundering of clothing are the principal applications of detergents.

The action of detergents include:

- Wetting of the surface and, in the case of textiles, penetration of the fibre structure by wash liquor containing the detergent.
- Absorption of a layer of the soap or **detergent** at the interfaces between the water and the surface to be washed and between the water and the soil.
- Dispersion of soil from the fibre or other material into the wash water. This step is aided by mechanical agitation and high temperature in devices such as washing machines.
- Preventing the soil from being deposited again onto the surface cleaned. The soap or **detergent** accomplishes this by suspending the dirt in a protective colloid, sometimes with the aid of special additives.

However detergents also are used as emulsifiers in many other applications. Detergents that function in non-aqueous media include:

- dispersing agents added to lubricating oils used in automotive engines to prevent the accumulation of varnish-like deposits on the cylinder walls,
- additives to petrol and diesel to prevent the build up of gummy residues in the carburettor, and
- additives to dry-cleaning solvents to facilitate the removal of soil from garments.



Activity 15. Survey of detergent use

- 1 *Survey the local store and garages or petrol stations to obtain information about the different detergents and their uses.*
- 2 *List the detergent, cleaning agent or additive and summarise in a table.*
- 3 *Research environmental effects of some of the substances.*

Brand	Substances contained	Claims by manufacturer	Environmental effects

4. Cement and Concrete

Cement and concrete has been around since before Roman times (over 3000 years ago) when a binding material was used to hold stones together. The Assyrians and Babylonians used moistened clay to bond building materials together. The Egyptians used gypsum which was heated in the same way that lime is made for betel nut consumption. The calcined gypsum was then mixed with sand to make a mortar used in the construction of the pyramids.

Natural gypsum is the mineral: $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. After heating it loses water to become $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$. This substance is known commonly as Plaster of Paris (named after the city where it was first researched as a binding agent). On adding water to Plaster of Paris it slowly reverts to the original formula thus chemically binding the mortar to the blocks of stone or bricks.

The Greeks produced lime in the same way that Solomon Islanders do, by heating limestone or coral deposits. They and the Romans improved the mortar or cement by adding volcanic ash. The art of cement making declined with the fall of the Roman Empire and wasn't further developed until 1824 by Joseph Aspdin who found that by heating a clay limestone to melting point. The fused product was then ground fine and became known as Portland Cement. A good cement contains a mixture of silicate compounds that form fibrous gels when reacting with water. They also contain Plaster of Paris and some calcium and magnesium oxides which form the hydroxides with water. Concrete is formed when cement, water, sand, gravel (aggregate) and air are combined. The strength of concrete is defined as its compressive strength and its tensile strength. The compressive strength is generally about 10 times that of the tensile strength. That is concrete is better at supporting large weights that compress it rather than bending under loads. Steel reinforcing is used to improve the tensile strength and in large buildings in cyclone and earthquake prone zones concrete should be prestressed. Single columns of concrete should also be poured in one go, not over a couple of days, as this weakens the concrete's ability to bend or stretch.

Why does concrete crack?

Expansive forces cause the cracking. In the setting stage this can be caused by rapid dehydration of the surface (exposed to the sun). Fresh concrete should be kept moist for a few days after pouring. Carbon dioxide can cause the pH to be alkaline which can interfere with the setting and growth of crystals. Salt water and sodium chloride can also cause chemical and mechanical damage to the concrete. Too much water in the mixture will also make the resulting concrete too weak. The reinforcing can begin to rust and expand making the concrete crack.



Activity 16 *Strength of concrete*

Materials

Moulds (UHT milk cartons), 100 mL measuring cylinder, 400 mL beakers, cement, water, plastic, plastic wrap, steel ballbearings, hammer.

Procedure

1. Prepare five moulds by cutting off the tops of some cardboard milk cartons. Label them 1, 2, 3, 4, 5.
2. Half-fill a 400 mL beaker with dry cement sand mixture.
3. Fill a 100 mL measuring cylinder with water.
4. Slowly add water a little at a time, with stirring, to the initially dry mixture. Continue adding water until the mixture becomes a thick paste. If you add too much water the mixture will suddenly become very thin and you will need to start again. When you have a thick mixture with no pockets of dry material, pour it into the first cardboard mould and scrape as much of the material out of the beaker as possible. Smooth the surface of the cement in the mould.
5. Wipe the inside of the beaker with a paper towel and rinse it well with water. How much water is left in the cylinder? Record the amount of water you used.
6. Dry the beaker and repeat the experiment, but this time with 20% less water. Repeat the experiment again, but with another 20% reduction in water. Repeat again with 20% more water than the first mixture.
7. Cover all four moulds with plastic wrap to prevent evaporation. Prepare one more sample identical to the first one you made, but leave this one uncovered. Leave all the moulds in a warm place for two days.
8. After two days examine the samples. Do the surfaces look different?
9. Scratch the surfaces with your fingernail, a nail or point of a file. Note any differences.
10. Try dropping steel ball or marble from the same height onto the surface of each sample. Wear safety glasses. The harder the surface, the greater will be the bounce height. Tear the cardboard off the samples and try a 'reproducible' hit with a hammer, of increasing intensity. Record the order of surface hardness by both methods and the resistance to breaking. What effect does the amount of water have? What difference does keeping cement under wraps make to the surface?

Extension

There are other parameters you might wish to explore, e.g. the ratio of sand to cement. Try mixtures varying from 50 mL sand plus 150 mL Portland cement, to 50 mL of cement plus 150 mL of sand. What is the effect of adding 1% sugar to an otherwise strong setting mixture?



Activity 17. Alkalinity of concrete

Materials

Steel reinforcing (or nails) and jars.

Procedure

Concrete is cement plus gravel and is often reinforced with steel rods. The steel is prevented from corroding because of the alkaline nature of the cement. Demonstrate this protection by placing pieces of steel reinforcing which has been cleaned of rust with sand paper, into two half filled jars of water. Into one jar also place some broken pieces of concrete. Seal the jars and leave for a week. The rod without the concrete should corrode faster.

Reactions

1. In exposed buildings, carbon dioxide from the atmosphere slowly penetrates the surface of concrete and reacts with lime, Ca(OH)_2 , converting it to limestone, CaCO_3 , the reverse of the process by which cement is made. This reduces the alkalinity of the surroundings of the steel which then can rust. The oxides and hydroxides of iron have a larger volume than the iron and this expansion cracks the concrete.

Obtain a broken piece of concrete where the surface has been exposed to the atmosphere for a while, e.g. from a building site. Break the piece open, and wet the whole new surface with some phenolphthalein indicator solution. A pink colouration will show the area of high alkalinity inside, with a rim of plain concrete around the edge. The extent to which the gas penetrates depends on the size of the pores in the concrete; the more water originally used, the larger the pores.