STELR

CHEMISTRY PROGRAM

STUDENT BOOKLET

NAME: ____ CLASS: _____

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GLOBAL WARMING

The melting of Arctic ice is one consequence of global warming and is leading to other consequences, including more extreme winter weather in Europe and North America.

BIG IDEAS

Should we be worried about the greenhouse effect?

Is global warming really happening? What evidence is there?

How might global warming affect our lives?

What is ocean acidification? And what is causing it?

1 GLOBAL WARMING AND CLIMATE CHANGE

Global warming is the term we use for the gradual increase in the average temperature at the Earth's surface that has occurred over the past century or so. Climate change is one of the consequences of global warming and will be discussed later.

Evidence for the increase in temperature

The following graph (Figure 1) shows there has been a gradual increase in the average annual temperature across Australia in the past century. The red graph shows the average maximum temperature for each year and the blue graph shows the average minimum temperature each year.

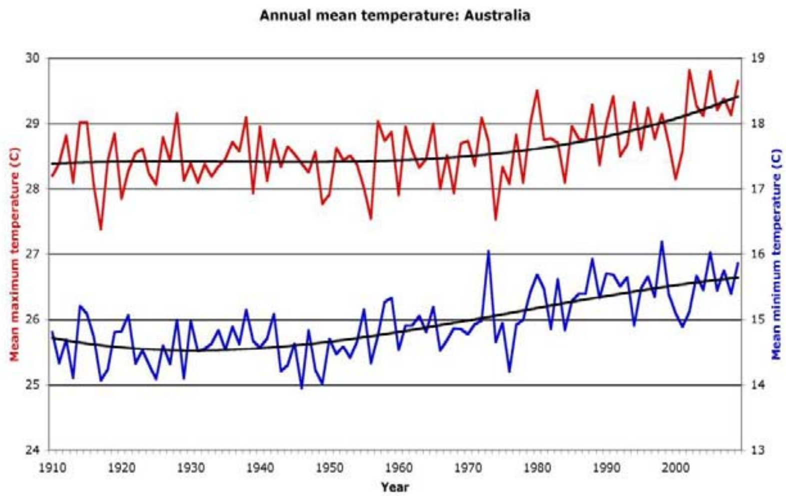


Figure 1

*Notice the curve that traces through the middle of the red graph. This is called a **trend line** – a line that smoothes out the fluctuations to show the trend in values. The graph points for this trend line are calculated using statistics. Similarly a trend line is drawn for the blue graph. It is clear that while the temperatures fluctuate (go up and down), there is an increase in the mean annual temperature.*

This increase in temperature everywhere across Australia also is shown in Figure 2. The map, prepared by the Australian Bureau of Meteorology, shows the average *change* in temperature per 10 years over the past century for each region.

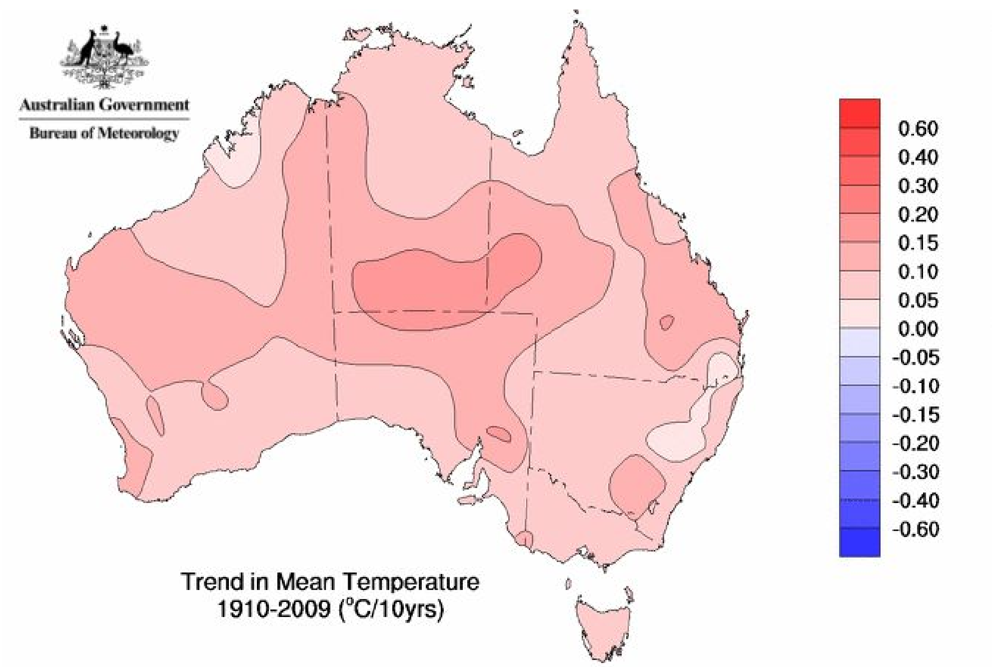


Figure 2 © Commonwealth of Australia 2010, Australian Bureau of Meteorology Issued: 06/01/2010

Like Figure 1 for Australia, the next graph (Figure 3) shows that there has been a gradual net rise in average temperatures across all countries over the past 130 years.

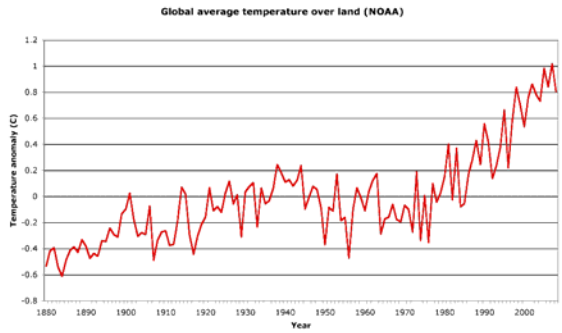


Figure 3

Note: The vertical scale shows the 'temperature anomaly', not the actual average temperature. ***Temperature anomaly*** *is a measure of how much the temperature is higher or lower than a long-term average. For example, a value of +1 means the average temperature was 1 ºC higher than the average temperature observed over a long time. A value of -0.6 means the average temperature was 0.6 ºC lower than the average temperature observed over a long time. This kind of graph is used by climate scientists to analyse trends in global temperatures.*

The graph in Figure 3 was constructed from temperature data collected from a network of 6000 temperature stations across the globe. These are shown in the following map (Figure 4). The colours show how long the stations have been keeping records. Approximately 1650 of these stations have kept records for longer than 100 years.

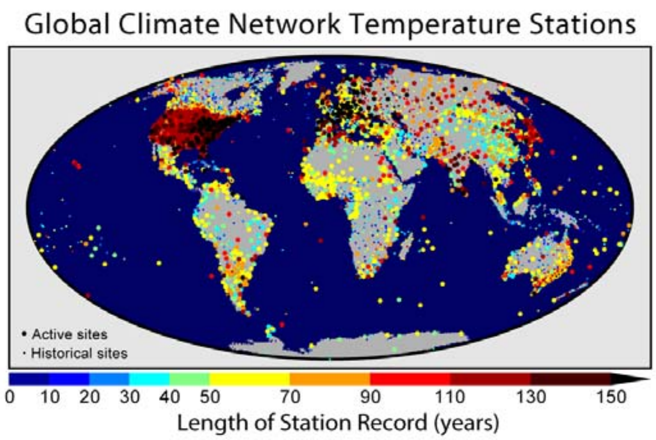


Figure 4

The next graph (Figure 5) shows the same trend over the months September-February, with satellite data shown in red.

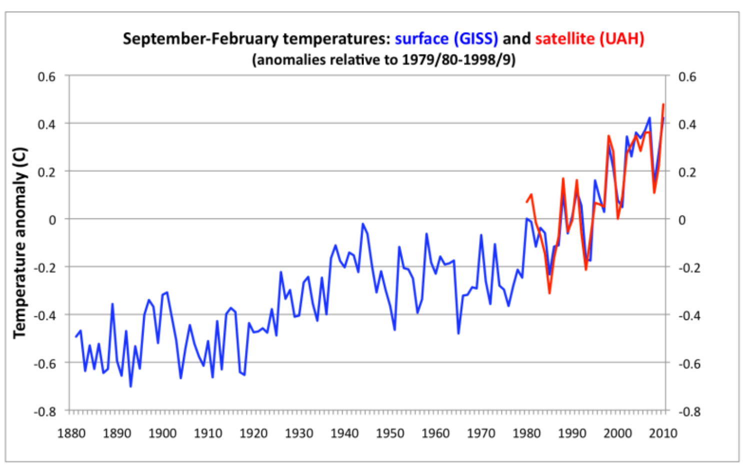


Figure 5

We can only conclude that there is overwhelming, reliable evidence that there has been a gradual increase in the temperature at the Earth's surface over the past 130 years.

Acknowledgement: The above graphs were provided by Professor Neville Nicholls, of Monash University. Professor Nicholls is a Lead Author for the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988.

Misleading information

It should be noted that some climate change sceptics take small parts of these graphs – parts where the graph line goes down – and use them to 'prove' that global temperatures are not rising. This is misusing the data. Long term-trends need to be examined if we are to draw valid evidence-based conclusions about what is happening to temperatures on Earth.

What is the cause of this gradual temperature rise?

Scientific modelling by atmospheric scientists and meteorologists, using data they have collected from ice core studies and measurements of atmospheric temperatures and gas concentrations in the atmosphere, indicates that the increase in concentration of the greenhouse gases in the atmosphere above their natural levels is the prime cause of global warming**.**

Greenhouse gases include carbon dioxide and water vapour. A number of other gases in the atmosphere also act as greenhouse gases, although the percentage of them in the lower atmosphere is much less than that of carbon dioxide and water. These gases include methane and nitrous oxide.

Greenhouse gases

Greenhouse gases all have one thing in common: their molecules contain 3 or more atoms. This is shown in the Table 1.

Table 1 Some of the main gases present in the lower atmosphere

Gas	Approximate percentage in the air (if water vapour is removed)**	Chemical formula	Total number of atoms in each molecule	Is this a greenhouse gas?
Oxygen	20.9	O_2	2	No
Nitrogen	78.1	N_2	2	No
Argon	0.9	Ar	1*	No
Carbon dioxide	0.04	CO_2	3	**Yes**
Methane	0.0002	CH_4	5	**Yes**
Nitrous oxide	0.00003	N_2O	3	**Yes**

**** Argon is classified as a noble gas. Noble gases exist in Nature as individual atoms, so these are not called molecules.***

***** The percentage of water vapour in the air varies from place to place and at different times, but on average is about 1-4%. The chemical formula of water is H_2O. It also is a greenhouse gas.***

The larger number of atoms in the molecules of greenhouse gases enables them to absorb infrared radiation radiated by the Earth's surface, and then emit some back to the surface. This warms the Earth even more.

Web research:

Look at the graph of variations in atmospheric carbon dioxide concentration and temperature during the past 400 000 years in the CSIRO article at: http://www.cmar.csiro.au/e-print/open/holper_2001b.html Do you think this is reasonable evidence of a link between the temperature of the atmosphere and carbon dioxide levels in the air?

What is infrared radiation and why is it important?

The light energy that is radiated out in Space by the Sun is not just the light you can see. In fact, out in Space, unless you are looking directly at a star, you can only see what we call visible light when it reflects off objects, such as the Moon or the International Space Station, or when it is 'scattered' by particles, such as the particles in the Earth's atmosphere, and enters your eyes.

Figure 6 The International Space Station (ISS) hovering above Earth. PHOTO CREDIT: Image supplied by NASA.
Notice the huge solar panels that help supply electrical power required to run the space station, and the astronaut on a spacewalk.

Besides visible light, the Sun also radiates out ultraviolet light (UV) and infrared light (IR). These cannot be seen with the unaided human eye. For this reason they are sometimes described as 'black light'. The whole range of radiation is known as the **electromagnetic spectrum**.

Figure 7 shows the electromagnetic spectrum. The Sun's radiation travels through Space in waves. For this reason the different parts of the spectrum are distinguished by the frequency of the waves, or their wavelength.

The highest energy radiation is gamma rays. Astronauts must be protected from this radiation when they go on a spacewalk, because it is highly penetrating. UV light has more energy than visible light, which is why it can be damaging if we are exposed to it too much. IR light has less energy than visible light, but is responsible for the warmth we feel. (Infrared lamps are used to warm bathrooms and to heat food.) Radio waves have very low energy.

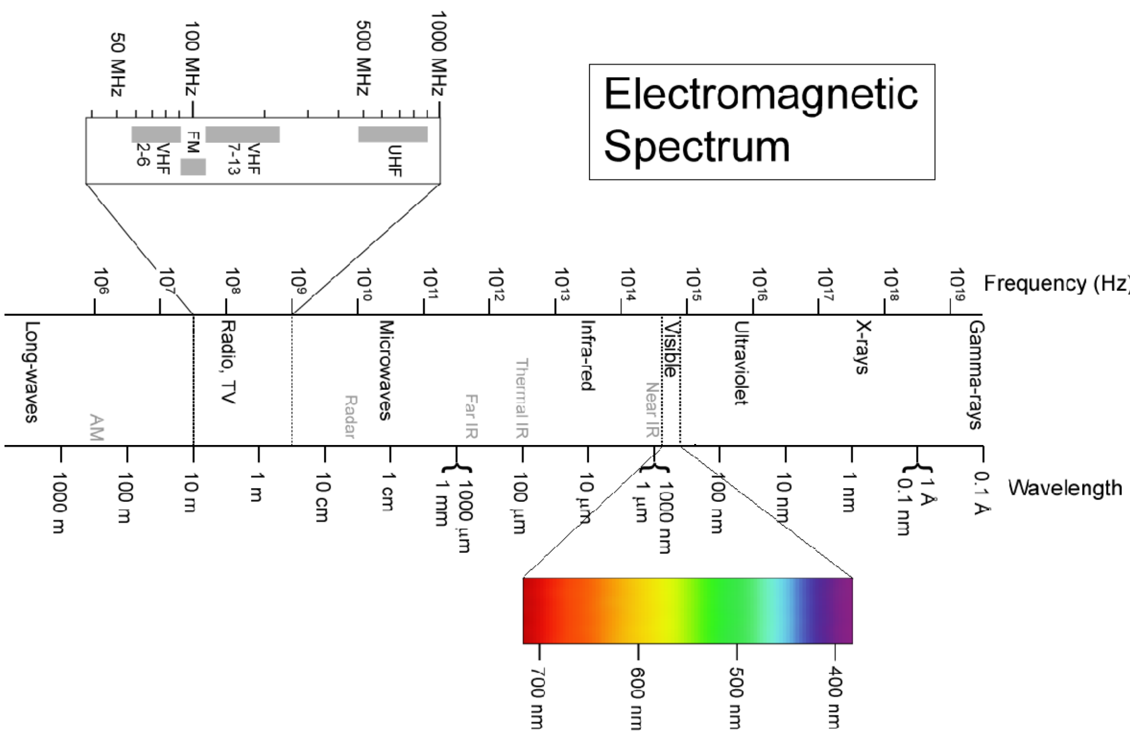


Figure 7 A schematic diagram of the electromagnetic spectrum.
Source: http://upload.wikimedia.org/wikipedia/commons/8/8a/Electromagnetic_Spectrum.png **Accessed:** 30 June 2010

Note in Figure 7: The band of wavelengths that match visible light has been expanded to show the colours that together make up visible light. Note there is actually a continual range of colours, not just the seven distinct colours listed in the well-known 'ROYGBIV' (Red, Orange, Yellow, Green, Blue, Indigo and Violet). Likewise, the band of wavelengths that are involved in radio and TV waves has been expanded to show some of the different broadcasting bands.

Did you know?

Of the different wavelengths that make up visible light, blue light is scattered more that the other wavelengths by the particles in the atmosphere. This is why the Earth is seen from Space as having a blue 'halo', as shown on the far right of Figure 6.

When the Sun's radiation reaches Earth

Figure 8 shows what happens to the Sun's radiation as it reaches the Earth.

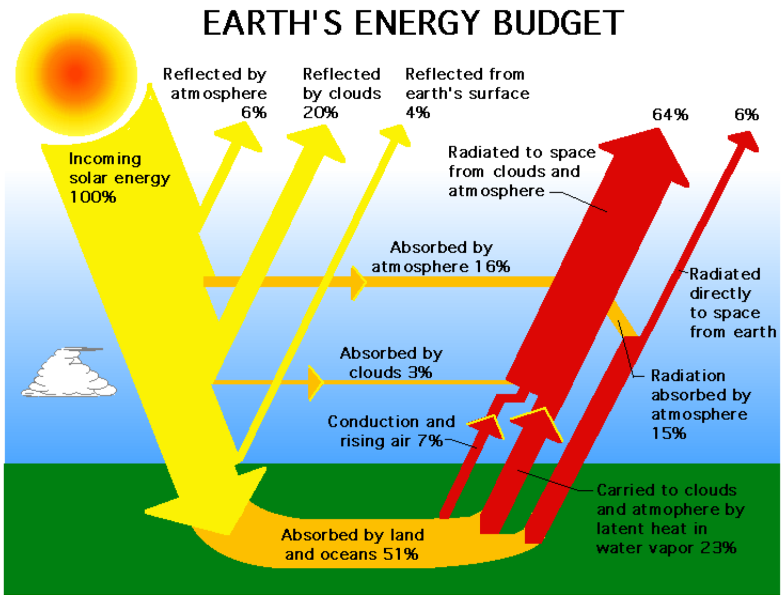


Figure 8

Notice that when the system is in balance, the total energy going out from Earth into Space adds up to 100 %, which means it equals the total energy coming in.

When radiation from the Sun reaches the Earth:

- About 30% of the radiation is reflected back into Space by the particles in the atmosphere, clouds and the Earth's surface. [In Figure 8 we see it is (6 + 20 + 4) %, which adds up to 30 %.]
- Some is absorbed by the water vapour in the atmosphere and by clouds. Some (about 3%) is absorbed by the ozone layer. (This layer is not shown in this diagram.) This adds up to about 19 %.

The remaining 51 % of the Sun's energy is absorbed by the Earth's surface (land and oceans). If it kept being absorbed and none was ever given back out, the Earth would get hotter and hotter. The oceans would have boiled away long ago, and all our water would have evaporated!

Fortunately for us, this does not happen, because the Earth radiates heat energy in the form of infrared radiation back into the atmosphere. And ultimately the atmosphere radiates heat energy back into Space. What happens to this infrared radiation in the atmosphere is of crucial importance to life on Earth.

Did you know?

All objects emit infrared radiation. We can see this radiation with special glasses. This fact is used by search and rescue teams, wildlife observers and others who need to see in the dark, such as cave explorers. The view they see is in shades of green. An example of a cave seen using night vision is shown in Figure 9.

Figure 9

The natural greenhouse effect

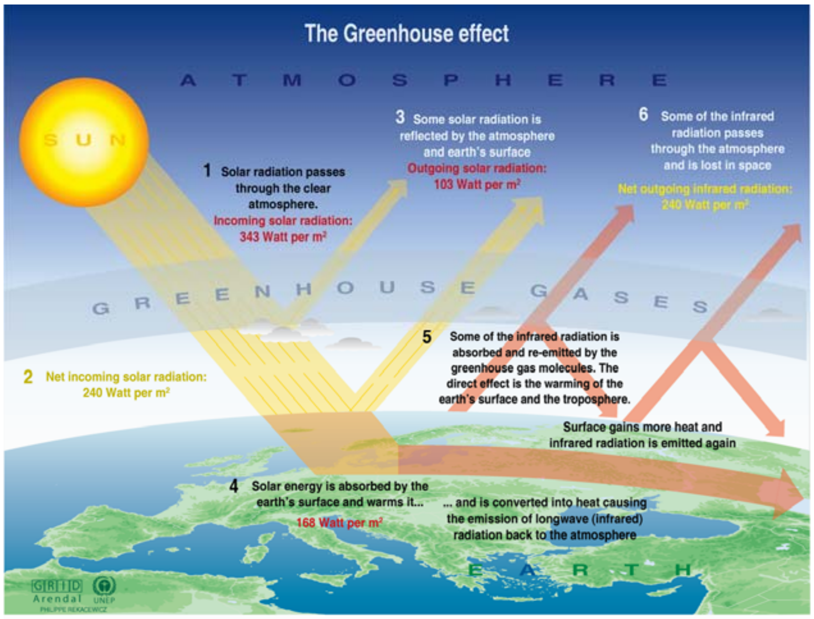
The **greenhouse effect** is the process whereby some of the infrared radiation emitted by the Earth's surface is 'trapped' by greenhouse gases, which helps moderate the temperatures at the Earth's surface.

The greenhouse effect has occurred naturally on Earth for millions of years, as our atmosphere has contained greenhouse gases ever since it first formed. For this reason this process, now known as the **natural greenhouse effect**, has enabled life to evolve on this planet. Without it, the temperatures experienced on Earth would be like those on the Moon, which is the same distance from the Sun as we are. This means it would be far too hot by day and far too cold by night for life as we know it to survive.

The Moon has no atmosphere and hence no greenhouse gases to help moderate the temperatures at its surface. This is why the average ground temperature on the Moon is -17 ºC, while on the Earth, which does have an atmosphere containing greenhouse gases, it is 16 ºC, which is 33 ºC higher.

In fact, when we say 'trapped', we mean that the molecules of greenhouse gases absorb some of the infrared radiation. They also emit some infrared radiation back to the Earth. This makes the temperatures at the surface warmer than they otherwise would be.

The natural greenhouse effect is illustrated in Figure 10.



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Figure 10

Cycling greenhouse gases

Over the millions of years in which the greenhouse gases have been present in the Earth's atmosphere, natural cycles have ensured that the proportion of the greenhouse gases in the atmosphere has remained steady. The 'cycles' consist of natural processes in which they are released into the air and other natural processes in which they are removed from the air.

Between the two kinds of processes, molecules of a particular gas are slowly and steadily cycled around. For example, the **carbon cycle** refers the processes in which carbon dioxide is released into the air and the processes in which it is removed from the air.

One of the natural processes in which carbon dioxide is released into the air is **cellular respiration**, a chemical reaction that can be summarised in the following word equation:

glucose + oxygen → carbon dioxide + water + energy

This reaction occurs in every cell within all those living organisms that undergo cellular respiration to obtain the energy they need to survive, including animals and plants. The carbon dioxide is then released into the air, as it is a waste product that would be toxic to the cells if it were to accumulate within the cells.

One of the natural processes in which carbon dioxide is removed from the air is **photosynthesis**. This is a chemical reaction in which plants and certain other organisms absorb carbon dioxide from the air and water from the ground to produce glucose.

carbon dioxide + water + energy → glucose + oxygen

The energy required for photosynthesis is obtained from light. The reaction also requires the presence of chlorophyll.

For more information on the carbon cycle and why it is necessary for life, see page 15.

Did you know?

Plants are not the only life forms that undergo photosynthesis. Aquatic organisms known as cyanobacteria, for example, also undergo photosynthesis.

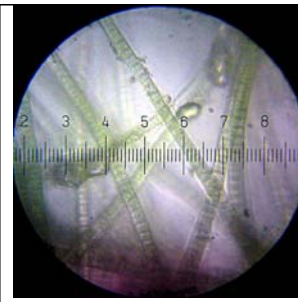


Figure 11 Cyanobacteria, seen under a microscope

Is there a balance?

Until the past century or so, all the natural processes in which greenhouse gases were released into the air and all the natural processes in which greenhouse gases were removed from the air balanced each other out. In other words, the gases were continually cycled around. As a result, the percentage of these gases in the atmosphere remained steady.

But now, the level of human activity we have today has altered this balance. Our large-scale burning of coal, natural gas and oil, our mass production of materials such as steel, cement and aluminium, and our huge piles of rotting garbage, not to mention burning trees to clear land or cutting them down to make goods (including paper), are releasing more greenhouse gas molecules into the air than can be removed in natural processes.

Even growing more and more rice and increasing the number of ruminant animals (animals that eat grass), such as sheep and cattle, to feed our increasing populations contributes to the problem. Rotting garbage, rice paddies and animals that eat grass and other plant material all produce huge amounts of methane gas, which is a far more potent greenhouse gas than carbon dioxide. (That is, a molecule of methane will emit more infrared radiation than a molecule of carbon dioxide.)

Insects that eat plant material or plant products such as wood or paper, add to this problem. Although each individual insect may only emit small amounts of methane, because there are billions of them, this adds up! Termites alone contribute hugely to the problem.

In addition, new very potent greenhouse gases such as nitrogen trifluoride, NF_3, are being introduced into the atmosphere as new technologies are developed.

Did you know?

Methane is produced by certain bacteria. In the case of rice paddies, bacteria break down dead plant material to obtain the nutrients they need. In the case of ruminant animals, bacteria live in their gut and break down the grass for them into a form they can digest. This is known as a symbiotic relationship, as both the animals and bacteria benefit from this arrangement. The methane is one of the waste products produced by the bacteria. (Unlike plants and animals, they do not produce carbon dioxide as a waste product.)

The enhanced greenhouse effect and global warming

The **enhanced greenhouse effect** is the trapping of additional infrared radiation by the excessive amounts of greenhouse gases in the atmosphere that have been produced as a result of human activity. It is this process that many scientists are concerned about.

See the next page for some likely consequences.

Likely consequences of global warming

Scientists use sophisticated computer models of the Earth that predict likely changes due to global warming. Some examples of the consequences of global warming include:

• **Climate change.** There are likely to be significant changes in climate around the world, including greater extremes of drought and heavy rainfall, and an increase in the severity of cyclones, typhoons and other extreme weather events.

•**Melting of polar icecaps and glaciers.** One consequence of this would be causing many species that are dependent on polar ice, such as the polar bear, to become endangered.

•**Change in weather patterns.** For example, some places may get more rain and storms while others may get less.

• **Increase in the temperature of the upper levels of the oceans.** One consequence of this would be damage to marine ecosystems due to the loss of species that cannot survive or cannot reproduce in the warmer water.

•**Rising sea levels.** This is mostly due to the expansion of the upper layers of the sea water due to the increase in temperature. The melting of the polar ice caps also contributes to this problem. This would result in the flooding of low-lying coastal areas. A large number of people would lose their homes and livelihoods.

•**The spread of tropical diseases.** The higher mean temperatures may lead to a wider spread of tropical diseases such as malaria, which is caused by a certain species of mosquito.

•**The spread of invasive species.** The change in climate is likely to lead to the movement of species that can cause damage to crops or stock. This could significantly reduce food supplies, which could lead to serious social problems. When people are hungry and desperate and either cannot access or cannot afford to purchase food from other regions, they could resort to uncontrolled use of toxic chemical sprays on crops and pasture, or to destroying more forests to obtain more land.

Some of these consequences are already being observed!

Sea-level rising

Scientific data shows how much sea levels are already rising. The graph in Figure 12 shows the increase in Global Mean Sea Level from 1993 to 2010. This shows the average across all the oceans.

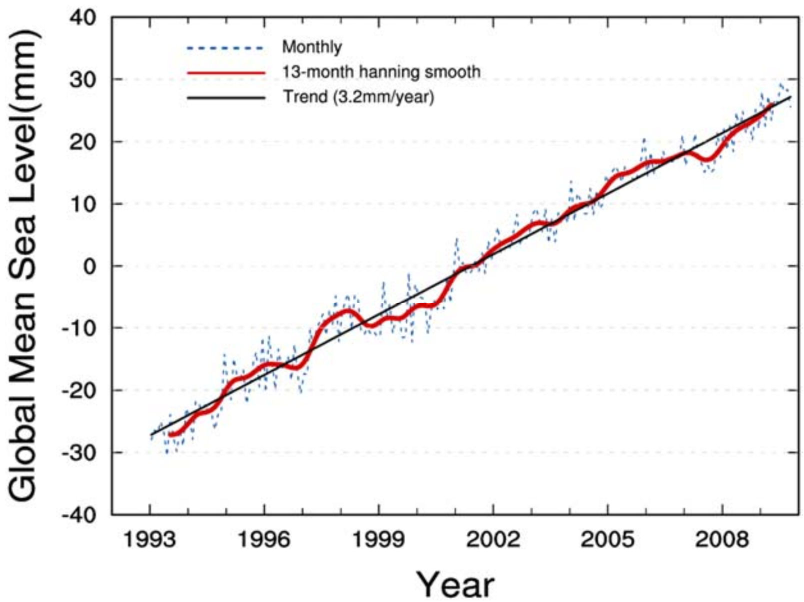


Figure 12

This graph shows how much the sea level is above or below a long-term average.

The world map in Figure 13 shows which areas of the ocean are rising more rapidly, and which are rising less rapidly. Notice that the northern parts of Australia are at the greatest risk of coastal flooding.

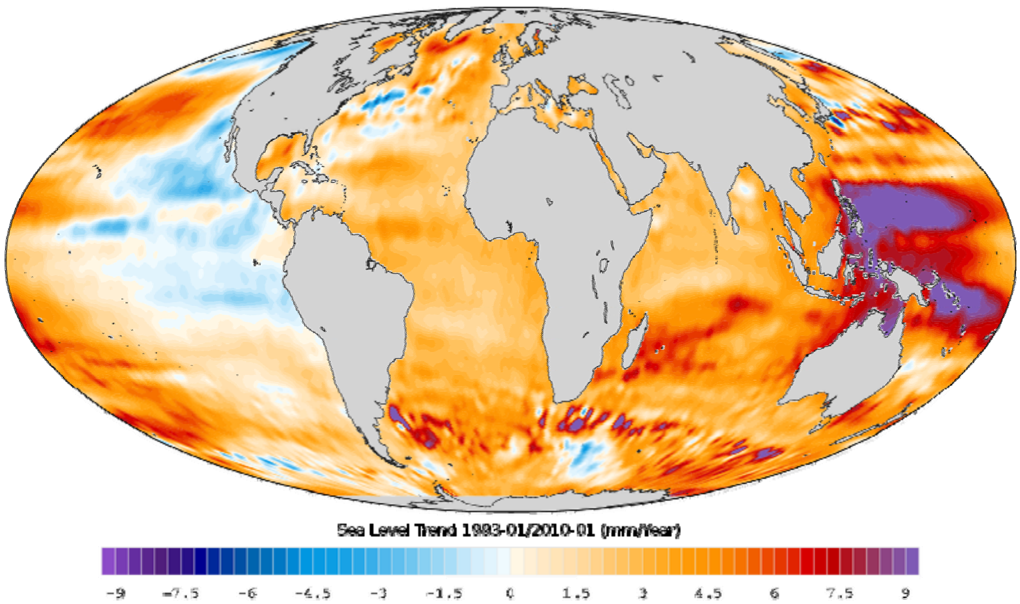


Figure 13

Melting of polar ice caps

One source of evidence for this is the large amount of satellite and other data collected by NASA scientists, seen in Figure 14.

Figure 14 NASA scientists studying ice in the Arctic. PHOTO CREDIT: NASA

Web research

Visit: http://www.nasa.gov/topics/earth/features/arctic_thinice.html Find out what NASA scientists have discovered. View the animation. What is your conclusion?

Did you know?

The enhanced greenhouse effect is not the only factor contributing to global warming. The vast amount of heat radiated out by big cities, especially from their centre, and huge industrial complexes, also contributes to the problem. However, its effect is very, very small compared with the enhanced greenhouse effect.

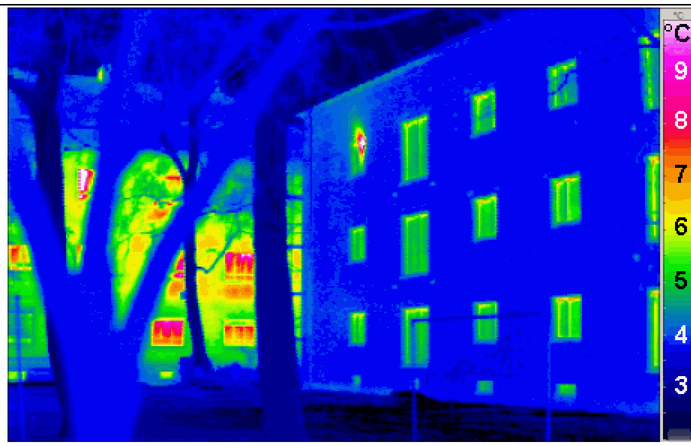


Figure 15

This image, known as a **thermogram**, was taken by a special infrared imaging technique in which the temperature of different regions is shown as different colours. This shows a building in the foreground which is well-insulated and not giving heat out into the environment (and so is termed a passive building), and a building in the background which is poorly insulated. Imagine what the thermogram of a fossil fuel power station would look like, with its furnaces and vast amounts of hot gases pouring out of chimneys!

Does the ozone layer have anything to do with global warming?

Many people mistakenly think the 'holes' in the ozone layer cause global warming. This is not so. They are entirely separate problems.

The **ozone layer** is a layer within the stratosphere, about 16 km above the Earth's surface, in which ozone is present.

Very few elements exist in Nature as separate atoms. The atoms of most elements are normally joined in some way to other atoms. One way they can be joined up is to form molecules**. Molecules** are particles that are made up of two or more atoms that are stuck together by electrostatic forces.

Ozone is a form of oxygen. 'Normal' oxygen exists naturally as molecules that contain two oxygen atoms. This is why it has the chemical formula O_2. Ozone molecules contain an additional oxygen atom and so have the chemical formula O_3.

Both 'normal' oxygen and ozone are present in the ozone layer. But they are constantly reacting. The ozone molecules keep reacting with one another, forming 'normal' oxygen molecules, and 'normal' oxygen molecules keep reacting with each other, forming ozone molecules. This is depicted in Figure 16.

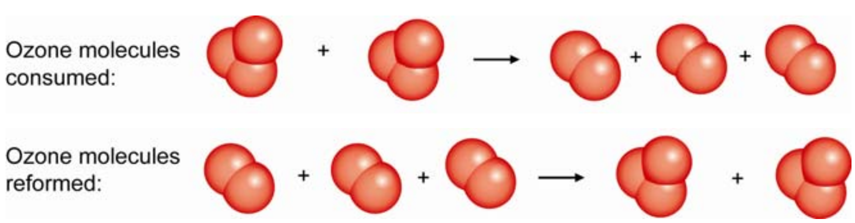


Figure 16 These models of molecules ozone and oxygen show how ozone molecules are constantly broken down to normal oxygen, and then produced again in the ozone layer

Each of these reactions uses some of the energy the Earth receives from the Sun. The energy is needed to overcome the electrostatic forces that stick the atoms together. Fortunately the energy that is needed to split the molecules is high-energy ultraviolet (UV) radiation. This is why the ozone layer absorbs a large proportion of the UV radiation the Earth receives from the Sun. As a result, we are exposed to much less UV radiation.

Did you know?

While our skin needs some exposure to UV radiation, in order to manufacture Vitamin D, too much exposure can cause problems such as skin cancers and cataracts.

A cataract is the clouding of the lens of the eye, as shown in Figure 17. Humans and most other animals are at risk of getting cataracts.

Figure 17 Untreated cataracts lead to blindness

The ‘holes’ in the ozone layer

Normally the reactions shown on page 11 are in balance. This means that for every ozone molecule broken down to normal oxygen another ozone molecule is made. Sometimes this balance is disturbed, however. As a result, in some parts of the ozone layer, especially in the region over the South Pole, the concentration of ozone (amount of ozone present in each litre of the air) has decreased. It has not disappeared altogether! Those areas in which the concentration of ozone is low are called **the holes in the ozone layer**.

The problem is that more UV radiation reaches the parts of Earth’s surface right under the ‘holes’. This means more people and other animals will get skin cancer and cataracts in those regions. So the ‘holes’ are of great concern.

What causes the ‘holes’?

The loss of ozone is caused by other chemical processes in which ozone molecules are broken down into normal oxygen. Some of these processes are occur naturally, such as those that cause the big ‘hole’ over Antarctica. However some are caused by chemicals produced by human activity. For example, one major cause was a family of chemicals commonly called CFCs. These were once widely used as propellants for aerosol sprays and as refrigerant gases because they are chemically stable. The problem with these is that each CFC molecule can last for more than100 years in the ozone layer, and during that time will ‘destroy’ billions of ozone molecules!

Once scientists realised this, many countries agreed to ban the use of CFCs. Their action has already made a huge difference to the problem. This is an excellent example of countries across the world taking action and working in cooperation with one another to reduce a global problem caused by human activity.

Ozone close the ground

There are other ways of making ozone besides the reaction making it in the ozone layer (page 11). Ozone also is produced in other processes that occur at the Earth’s surface. These include:

• Running photocopiers and other devices that use electronic flashes.
• The action of sunlight on the exhaust gases emitted by motor vehicles.

The ozone close to the ground is classified as a pollutant. When breathed in, it can cause many health problems, including difficulty breathing.

It also contributes to global warming. Since ozone molecules at this level do contain 3 atoms, any ozone close to the surface acts as a greenhouse gas.

So although the ozone layer itself does not cause global warming, the ozone produced near the ground as a result of human activity does contribute to global warming.

Discussion questions

1 Which of the following gases are greenhouse gases? Highlight the correct responses.

A Oxygen
B Methane
C Steam
D Nitrogen
E Carbon dioxide
F Ozone

2 Which of the following are contributing to global warming? Highlight the correct responses.

A The building of large cities
B Burning coal to generate electricity
C The holes in the ozone layer
D Large-scale manufacturing of steel
E Grazing large numbers of sheep
F Paper manufacture

3 Many people believe that the flooding of low-lying coastal areas that has been observed in some areas is due to the melting of polar ice caps. Is this the main cause of the flooding? Discuss.

____

____

4 a Explain the difference in meaning between the natural greenhouse effect and the enhanced greenhouse effect.

____

____

____

b Explain why one has helped life to exist while the other is likely to lead to serious consequences which are more likely to endanger life.

____

____

____

5 Fill in the gaps:

The ozone layer is a layer of ozone located about _____ km above the Earth's surface. Ozone is a form of _________ in which there are _____ atoms in each molecule instead of the usual _____. Also present in this layer is __________.

In this layer, chemical reactions are continually taking place. In one reaction ozone is converted to __________ and in the other reaction ________ is converted to _____________. These reactions are in ____________with one another and keep the concentration of ozone ________. (Concentration means ___________________________________.)

These reactions both require a lot of energy, and so much of the _______ radiation from the Sun is absorbed by the molecules as they react. This means that the amount of _____ radiation reaching the Earth's surface is _______.

The problem is that in some regions, especially above Antarctica, the concentration of ozone has __________. We say there is a _______ in the ozone layer in these regions. This means that people and other animals living under these regions are more likely to develop ___________ and _____________.

6 Explain why in the late 1980s many countries agreed to ban the use of CFCs as refrigerant gases and propellants for aerosol sprays such as spray-on deodorants.

____

7 Is there any ozone near the Earth's surface? If there is, is this a good thing, or not? Discuss.

____

2 THE GLOBAL WARMING DVD

1 What were some new facts you learned about global warming from the DVD? Place your answers in the table.

What is global warming?
What is causing global warming?
What is some evidence that global warming is occurring?
How are scientists investigating this problem?
What might be some possible consequences of global warming in the future?

2 What questions do you still have about global warming?

3 What is your opinion of the DVD? Did any of its contents surprise you? Do you think it would convince climate-change-sceptics to investigate the issue further and perhaps change their mind?

What worked and what didn't in the way it was presented? How would you improve the DVD if you were the producer?

4 Design a concept map to show how various aspects of global warming are related to each other. Incorporate the following key words into your concept map. Can you think of any other key words? Add them into your concept map as well.

Global warming	Energy from the Sun
Methane	Ice cores
Greenhouse gases	Thermal expansion
The greenhouse effect	Temperature
The enhanced greenhouse effect	The atmosphere
Extreme weather events	Refugees
Rising ocean levels	Flooding
Carbon dioxide	Balance

3 THE CARBON CYCLE

Carbon – the element of life

Like everything else in our world, all living things are made up of extremely tiny particles known as atoms. What is special about living things is that our bodies have been built from carbon atoms.

In the case of humans and other mammals, for example, our muscle tissue, nerve fibres, blood vessels, skin, hair and bones are all constructed from carbon atoms. Even our DNA is made from carbon atoms. The carbon atoms are not present just by themselves, however. Atoms of a small number of other elements, such as oxygen and hydrogen, are attached to the carbon atoms.

Of course the water in our bodies and some other substances, such as the acid in our stomachs and most of the mineral salts, are not constructed from carbon atoms. Nevertheless, it is easy to see why carbon is often described as the 'element of life'.

How do we get the carbon we need?

From the time you were a tiny embryo, your body has kept growing. This means that more and more atoms have been added. Your body cannot make carbon atoms or any other atoms – it can only build up materials from atoms with which it has been supplied. So where do they come from?

At first the atoms were supplied from the nutrients present in your mother's blood, which flowed to your body through the umbilical cord from the placenta. Since you were born, they have all been obtained from your food.

Figure 1 A human embryo, connected to its mother's placenta.

Star child? Recycled dinosaur?

Ultimately, where did all atoms in your body come from?

It may surprise you to know that scientists believe that all the atoms on Earth, including in your body, were created in ancient stars more than 4 billion years ago. Apart from atoms lost from Earth in any spacecraft and space junk that will never return to Earth, and any atoms added when meteors have landed on Earth, the number of atoms present on Earth has not changed. All that happens is they are recycled!

So, for all you know, some of the atoms in your body may once have been part of a dinosaur. Certainly, if the atoms in your body could talk, they would have an extraordinary tale to tell of where they have been over their billions of years of existence.

How does carbon get recycled?

Carbon is mostly cycled through the carbon dioxide in the atmosphere. As you learned on page 7, there are processes by which it is added to the atmosphere and processes by which it is removed. This cycling of carbon via carbon dioxide is known as the **carbon cycle**. One simple representation of the carbon cycle is shown in Figure 2 on page 16.

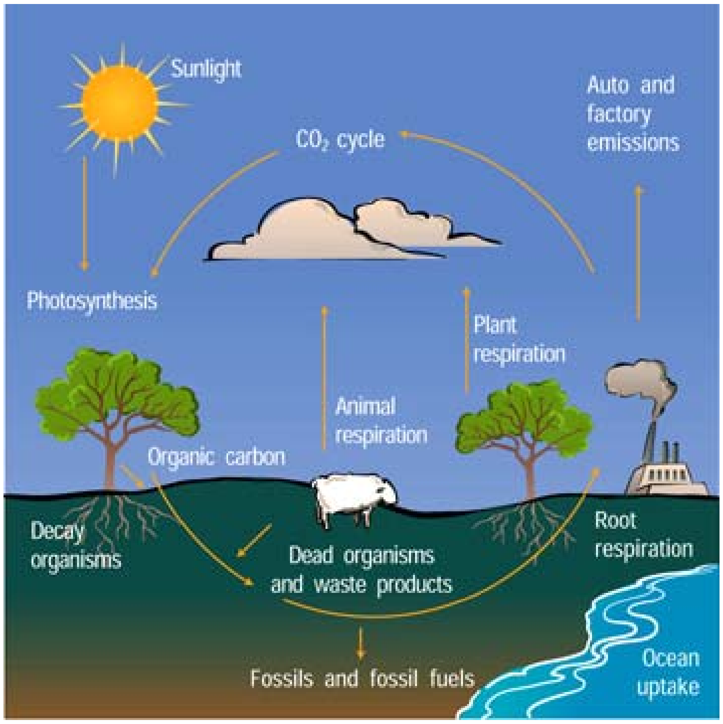


Figure 2 One representation of the carbon cycle. Organic carbon means carbon bound up in living organisms and in their waste products.

Processes that add carbon dioxide to the atmosphere

In diagrams of the carbon cycle, up arrows are used to represent processes that add carbon dioxide to the atmosphere. They include chemical processes by which living organisms obtain their energy, such as:

- **Cellular respiration:** glucose + oxygen → carbon dioxide + water + energy
- **Fermentation:** glucose → carbon dioxide + alcohol + energy *(This process is not listed in Figure 2)*

Processes that remove carbon dioxide from the atmosphere

In diagrams of the carbon cycle, down arrows are used to represent processes that remove carbon dioxide from the atmosphere such as:

- **Photosynthesis:** carbon dioxide + water + energy → glucose + oxygen
- **Formation of shells, corals, stalactites and stalagmites etc.** *(This process is not listed in Figure 2)*

It may take over a hundred years for a particular carbon atom to enter the atmosphere, then be absorbed by a plant and converted into a sugar or other substance, then be eaten by animals and converted to a new substance, and eventually eaten by you in a great roast dinner!

Some carbon atoms are taken 'out of the loop' for thousands of years, however, by being converted to fossil fuels such as coal and oil. That is, until we burn them . . .

It is hard to imagine, but in this roast dinner alone there would be more than 3 000 000 000 000 000 000 000 000 carbon atoms!

If the dinner was accidentally burnt, the black charcoal that would be left would be practically pure carbon.

Discussion questions

1 True or false? Circle the true statements. Rewrite any false statements on the lines below to make them true.

A Every substance in your body contains carbon atoms.

B Your body cannot manufacture carbon atoms.

C The carbon cycle refers to the evaporation and condensation of carbon dioxide via the atmosphere.

D Photosynthesis is the process by which plants add carbon dioxide to the atmosphere.

E Once carbon is converted to a fossil fuel, it is locked out of the carbon cycle forever.

F Bones are just made from carbon atoms.

G Once a carbon atom enters your body, it never can leave.

____

____

____

2 What do you think of the idea that according to scientists, all the atoms in your body are billions of years old and were created in a star? What questions would you want to ask those scientists?

____

____

____

3 Research the internet and other reference material and find an alternative representation of the carbon cycle. Copy the image and compare how useful it is and how easy it is to understand with the representation in Figure 2.

4 Create a different way to represent the carbon cycle and its importance. Ideas include creative movement, music, dance, theatre and sculpture.

5 Explain why:

a Carbon is often called the element of life.

____

b For life to exist, carbon atoms must be recycled .

____

c It is often said “You are what you eat.”.

____

d Scientists are worried that the amount of carbon dioxide added to the atmosphere is out of balance with the amount of carbon dioxide removed from it.

____

____

____

4 WHAT'S HAPPENING IN OUR OCEANS?

There is some evidence that our oceans are becoming more acidic, particularly in some regions. There is some evidence to suggest that one cause of this may be the build-up of greater amounts of carbon dioxide in the atmosphere in the past century or so, due to human activity.

You will be investigating this next. But first you need to know about acids and bases and pH.

What are acids and bases?

Acids are substances that will corrode metals and also react with substances such as calcium carbonate, which is the main substance present in shells and coral, the shells of bird eggs, limestone and marble, stalactites and stalagmites. Vinegar contains an acid. Its common name is acetic acid but its proper chemical name is ethanoic acid. Lemons, oranges and other citrus fruits contain another acid, which is commonly known as citric acid.

Figure 1 Stalactites and stalagmites are mainly made from calcium carbonate. These ones are a rich-red-brown colour because iron compounds are also present. (Calcium carbonate is white.)

Bases are substances other than metals that react with acids. Calcium carbonate is an example of a base. It does not dissolve in water but it will dissolve in acids as it reacts with them. Bases that are soluble in water are also known as **alkalis**. An example of an alkali is sodium hydroxide.

Neutral substances are neither acidic nor basic. Pure water is an example of a neutral substance .

What kind of solution is it?

Solutions can be classified as acidic or basic or neutral using substances known as **acid-base indicators**. These substances change colour depending on whether they are added to an acidic or a basic solution. Many plants such as purple cabbage contain substances that change colour like this.

pH

The **pH** of a solution is a measurement of how acidic it is. See Figure 2 below.

How handy is this?

Universal indicator is a very handy acid-base indicator. In fact it is a mixture of several indicators, which can turn through a range of colours to show if a solution is strongly or weakly acidic, or strongly or weakly basic, or neutral. It even indicates the approximate pH of the solution! Figure 2 shows the colour range for one brand of universal indicator solution.

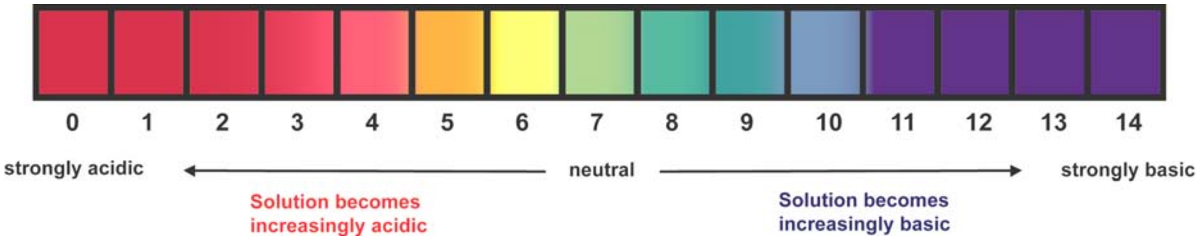


Figure 2 The colour range for a universal indicator solution that distinguishes between pH values 3-11.

It is important to know that:

• The *lower* the pH, the *__more acidic__* it is!

- **Acidic solutions** are solutions that contain one or more acids and have a pH below 7.
- **Basic solutions** are solutions that contain one or more bases and have a pH above 7.
- **Neutral solutions** and **pure water** are neither acidic nor basic and have a pH of 7.
- When exactly the right amount of an acidic solution is mixed with a certain basic solution, the acids and bases present will react with each other and a neutral solution will be produced. This called a **neutralisation reaction**.

Warning!
Although many foods are acidic or basic, and are safe to handle and eat, there are many acids and bases used in industry or in the laboratory that are very dangerous. These include sulfuric acid and sodium hydroxide. They can severely burn your skin and eyes. They must be handled with very great care.

It's a fact!
Most aquatic organisms can only survive in water within a pH range of 7 to 8.2. These include the organisms that build our coral reefs, known as coral polyps.

Figure 3 These new coral polyps will only survive if the pH, temperature and salt content of the water is just right!

Figure 4 Bleaching of corals occurs when the conditions are not right. The coral polyps have died.

Quick quiz on acids and bases

1 Which one or more of these statements about acids are **correct**?
A Acids have a pH higher than 7.
B Acids can 'eat' into metals.
C No acid should be swallowed.
D Acids can neutralise bases.

2 Which one or more of these statements about bases are **correct**?
A Bases have a higher pH than acids.
B Bases can dissolve in acids.
C Corals are made from a base.
D All bases are called alkalis.

3 Which one or more of these statements about acid-base indicators are **correct**?
A All acid-base indicators have a range of colours.
B Acid-base indicators can be made from certain plants.
C Universal indicator is a mixture of indicators.
D Universal indicator turns green in pure water.

PRACTICAL ACTIVITY 1: WHAT'S HAPPENING IN OUR OCEANS?

Partners: ____ **Date:** ____________

Inquiry questions

1 What everyday substances are acidic, basic or neutral?
2 What happens to the pH of sea water if extra carbon dioxide dissolves in it?
3 What might be the impact on the shells of shell fish if, as a result of human activity, extra carbon dioxide dissolves in the oceans?
4 What might be the impact on the shells of shell fish if, as a result of human activity, acidic substances move into the sea from our waterways, etc.?

Figure 1

Introduction

In this activity, you will test the acidity of a range of foods and soaps and detergents as well as sea water and carbon dioxide solution.

You will then see what happens to the pH of sea water when you blow air from your lungs into it.

Finally you will discover what happens to sea shells or other forms of calcium carbonate when they are placed in different solutions. One of these solutions is soda water, which contains a little salt, but not nearly as much as sea water. Carbon dioxide has been bubbled into this under pressure. This means that soda water in a bottle that is sealed tight contains far more carbon dioxide than is dissolved in our oceans. When you open a new bottle of soda water, however, a lot of this carbon dioxide bubbles back out.

Note: It is important to use the colour chart that accompanies the universal indicator solution you use! For an example of a colour chart, see Figure 2 on page 18.

What you need

- Small dropper bottle of universal indicator & chart
- Large dropper bottle of sea water
- Small-scale testing equipment, as supplied
- Droppers and small plastic teaspoons
- 5 x 100 mL conical flasks
- A4 sheet of white paper (or large white tiles)
- Labelling system for testing, as supplied
- Small samples of foods, and soaps and detergents
- Small jar of broken or crushed sea shells or shell grit
- Small spatula
- Small beaker of tap water
- 1 x drinking straw
- Paper towel

Assessing the risks

Read the facts, imagine what could happen that might hurt someone or cause damage, and think of what you could do to prevent that problem. Hence complete Table 1.

Table 1 Risk Assessment

The facts	What might be the risks?	What precautions will we take?
1 Acidic solutions can sting your eyes or broken skin. Basic solutions can irritate eyes. (You will not be testing strongly acidic or basic solutions.)		
2 Universal indicator solution can stain skin and clothes etc.		
3 Universal indicator solution is poisonous.		

What to do and what you discover

PART A

Inquiry question 1: What everyday substances are acidic, basic or neutral?

Table 2 Instructions for Part A

Step	What to do
1	Set up the testing equipment and labelling system your teacher has supplied. You will be testing foods and soaps and detergents, plus tap water and sea water, as demonstrated by your teacher.
2	In the space provided on the next page, draw up a results table to record all the foods you tested, the colour of the indicator, and the approximate pH of the solution.
3	In the case of the solutions you are testing, place a few drops of each solution in the appropriate well or other container, according to your labelling system. In the case of substances that have a thicker consistency, such as yoghurt, use a small teaspoon to add the substance to its well or other container.
4	If your samples are not sitting over a white background, then place them over white paper (or white tiles) so you can clearly see the colour changes that will occur when you add universal indicator solution to them.
5	Drop 2 or more drops of universal indicator solution onto each substance until the colour of the indicator can be seen (without it being too bright). **Do not get any of the substances onto the dropper from the bottle of universal indicator, or the dropper will become contaminated!**
6	If you also have been provided with slices of fresh fruit and vegetables, place each slice over a piece of paper towel then place 1-2 drops of universal indicator solution onto the centre of the fruit. Let it soak into the fruit. **SAFETY WARNING!** **Don't eat the fruit. Remember universal indicator is poisonous and food should NEVER be eaten in a laboratory!**
7	Record the substances you tested, the indicator colours, and the approximate pH from the pH colour chart, in Table 3, and hence classify the substance as acidic or basic or neutral.
8	Place the washable testing equipment in the tub of cold water provided. Wrap the fruit and vegetable slices in the paper towel and place them in the bin provided.

Table 3 Results for Part A

Conclusion for Part A

From your results in Part A, what is your response to Inquiry Question 1: What everyday substances are acidic, basic or neutral?

Use Table 4 to display your answer.

Table 4 Conclusion for Part A

Acidic substances	Basic substances	Neutral substances

Discussion questions for Part A

1 Did any of these results surprise you? Discuss.

____

____

2 An acidic solution with a pH of about 5 or 6 is classified as weakly acidic. In Table 4 above, highlight or underline those substances that would be classified as weakly acidic.

3 A basic solution with a pH of about 8 or 9 is classified weakly basic. In Table 4 above, highlight or underline those substances that would be classified as weakly basic.

4 Long ago, some scientists used to identify substances that were acids or bases by tasting them. They said acids were substances that tasted sour and bases were substances that tasted bitter. What was wrong with this kind of testing?

____

____

PART B

Inquiry question 2: What happens to the pH of sea water if extra carbon dioxide dissolves in it?

Note: Carbon dioxide is produced in cellular respiration, the chemical reaction that occurs in your body cells to provide them with the energy they need to carry out their work.

Cellular respiration: glucose + oxygen → carbon dioxide + water + energy

If too much carbon dioxide was dissolved in our blood, we would become very ill. So our body constantly removes the excess carbon dioxide via our lungs. For this reason, you breathe out more carbon dioxide than you breathe in.

Sea water already contains dissolved carbon dioxide. When you blow into the sea water, you will dissolve extra carbon dioxide in it.

Figure 1 Blowing extra carbon dioxide into sea water, to which universal indicator has been added.

Table 5 Instructions for Part B

Step	What to do
1	Add sea water to one of the conical flasks until it is about a quarter full. Place the flask over white paper or a white tile, as shown in Figure 1. Then add enough drops of universal indicator solution to the water to make its colour obvious, but not too bright. Record the indicator colour and approximate pH in Table 6.
2	Choose a group member to blow into the sea water. Place the drinking straw into the water well below its surface, then blow bubbles into the water for about 1-2 minutes. Record what happens to the indicator colour and the pH of the solution in Table 6. **SAFETY WARNING!** **Take care that you only blow into the straw. Do not suck any liquid back up into the straw! Remember universal indicator is poisonous!**
3	Label the flask to show it contains sea water with carbon dioxide blown in, and keep it aside for Part C. Place the used straw in the bin.

Table 6 Results for Part B

Time	What colour is the universal indicator solution?	What is the approximate pH of the solution?
Before blowing the carbon dioxide into the sea water		
After blowing carbon dioxide into the sea water		
What else did you observe?		

Conclusion for Part B

From your results in Part B, what is your response to Inquiry Question 2: What happens to the pH of sea water if extra carbon dioxide dissolves in it?

____

____

Discussion question for Part B

Our oceans absorb a lot of carbon dioxide from the atmosphere. From your results, what might happen to the pH of sea water if more and more carbon dioxide were to dissolve in it? Discuss.

____

____

PART C

Inquiry question 3: What might be the impact on the shells of shell fish if, as a result of human activity, extra carbon dioxide dissolves in the oceans?

Inquiry question 4: What might be the impact on the shells of shell fish if, as a result of human activity, acidic substances move into the sea from our waterways, etc.?

Figure 2 The solutions to which the sea shells will be added. The labels are not shown so you can discover what the missing labels would be for yourself!

Table 7 Instructions for Part C

Step	What to do
1	Place the flask of sea water and extra carbon dioxide from Part B and the four empty conical flasks over the sheet of white paper. For the four empty flasks, label them to show whether they will contain tap water, sea water, vinegar or soda water.
2	Add the solutions to each of the four empty conical flasks, according to your labels, until each flask is about a quarter-full. Make sure each flask is filled to the same depth.

3	Add a few drops of universal indicator solution to each of the four colourless solutions. Ensure you put the same number of drops of indicator in each flask. Your set of solutions should now look like those in Figure 2, though yours will show the labels!
4	Record the indicator colour and approximate pH of the solution in each flask in Table 8.
5	Use the spatula to drop in a spatula-full of broken shells or shell grit, or other source of calcium carbonate supplied to you, to each of the flasks. Make sure you put the same amount into each flask! Then gently swirl the flasks and observe what happens. Record your observations in the third and last column of Table 8.
6	Observe any changes to the solutions and shells over a period of 3 days, and record your results in Table 8 . Then pack up according to your teacher's directions.

Table 8 Results for Part C

Solutions to which the sea shells were added	**Before the sea shells were added**		**About 30 minutes later**		**After 3 days**		**What changes happened to the sea shells/ shell grit?**
	Indicator colour	**Approx pH**	**Indicator colour**	**Approx pH**	**Indicator colour**	**Approx pH**	
Tap water							
Sea water							
Vinegar							
Soda water							
Solution from Part B (sea water into which extra CO_2 was bubbled)							

Conclusion for Part C

From your results in Part C, what is your response to Inquiry Question 3: What might be the impact on the shells of shell fish if, as a result of human activity, extra carbon dioxide dissolves in the oceans?

____

____

From your results in Part C, what is your response to Inquiry Question 4: What might be the impact on the shells of shell fish if, as a result of human activity, acidic substances move into the sea from our waterways, etc.?

____

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Discussion questions for Part C

1 What might be the impact on shell fish if, as the result of human activity, extra carbon dioxide dissolves in the oceans AND acidic substances move into the water as well? Discuss.

____

____

2 Suggest explanations for the changes in pH of the solutions and changes to the shells observed in Part C.

____

____

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3 Suggest why:

a You were instructed to put the same amount of liquid, the same amount of shell and the same amount of indicator into each flask.

____

____

b You tested the shells in tap water and sea water as well as the vinegar, soda water and sea water into which carbon dioxide has been bubbled.

____

____

c The flasks were not sealed tight with rubber stoppers.

____

____

Find out!

Many marine scientists are concerned about 'ocean acidification' due to the build-up of carbon dioxide in the atmosphere beyond its natural levels.

1 Does the term 'ocean acidification' mean that the oceans are actually acidic, or just that their pH is dropping and they are becoming less basic?

2 What evidence do the scientists have?

3 Is the increased level of carbon dioxide the only cause of ocean acidification?

4 What consequences have marine scientists detected already and what do they think might be the long-term consequences?

5 Use the web to find out more about this issue. Two of the many websites about ocean acidification are as follows:

www.pacificscience.org/tfoceanacidification.html

www.antarctica.gov.au/about-antarctica/fact-files/climate-change/ocean-acidification-and-the-southern-ocean

ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

A hydroelectric power station uses energy transformations and energy transfers to generate electricity. This photograph shows the pipes that carry water down from the dam to the hydroelectric power station. The used water is then discharged into the waterway next to the power station.

BIG IDEAS

What kinds of energy are there?

Can you create or destroy energy?

What happens inside a hydroelectric power station?

What are the consequences of our energy production and use?

5 ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

What kinds of energy are there?

Before we consider any energy transformations and energy transfers, we need to be clear about what energy is.

Energy is associated with any change. It can be thought of as the ability to make something happen. It is *not* a force! A **force** is simply a push or a pull or a twist.

There are many different forms of energy but two fundamental forms are **kinetic energy** and **potential energy**. Some common forms of energy are shown in the table below.

FUNDAMENTAL FORM OF ENERGY	MEANING	SPECIAL CASES: DISCUSSION	EXAMPLES
KINETIC ENERGY	Kinetic energy is the energy of moving objects.	**Mechanical energy** When a machine is working, its kinetic energy is sometimes called mechanical energy.	 Figure 1 When it is set spinning, a turbine has mechanical energy
		Thermal energy/ heat energy The coldest possible temperature anywhere in the universe, -273 ºC, is called Absolute Zero. Unless a substance is at this temperature, the atoms or molecules present in the substance are moving in some way. The higher the temperature, the greater their average kinetic energy. Because it is related to their temperature, this energy is sometimes termed thermal energy or heat energy. ***Note:*** Any object that has thermal energy gives out infrared radiation (see page 5.)	 Figure 2 The water molecules in this glass of tap water have thermal energy. So do the atoms in the glass itself.
		Sound energy When sound is transmitted through air, or water or any other medium, the particles in the air, water or other medium begin to vibrate (move back and forth). When this occurs, we can hear the sound, so their kinetic energy is described as sound energy.	 Figure 3 When a drum is beaten, the vibrating drum skin sets the air particles near it into vibration. The air and the drum skin have sound energy.

POTENTIAL ENERGY	We can think of potential energy as stored energy.	**Gravitational potential energy** A raised object can fall downwards due to the force of gravity, if it is no longer held up. So we say it has gravitational potential energy.	 Figure 4 Water stored up high in the Gordon Dam, Tasmania, has gravitational potential energy.
		Elastic potential energy Any stretched or compressed elastic object can return to its natural shape if it is no longer prevented from doing so. So we say it has elastic potential energy.	 Figure 5 A stretched rubber band has elastic potential energy.  Figure 6 This spring has been compressed to test it. It has elastic potential energy.
		Chemical potential energy Any chemical substance that can react with other substances has the ability to give out heat or light. We say it has chemical potential energy.	 Figure 7 The gas in these cylinders can burn. It has chemical potential energy.

Note:

Electrical energy is the energy possessed by electrically charged particles, which may be associated with an electric current or stored charge.

Light energy is the energy of visible light, ultraviolet light, infrared light, X-rays and other forms of electromagnetic radiation.

CHANGING FROM ONE FORM OF ENERGY TO ANOTHER

Energy can be changed from one form to another. When this occurs, the process is described as a **transformation** of energy.

The following examples show this.

The energy transformations involved in turning on a radio

When you turn on a radio that is plugged into a power point, electrical energy is transformed into sound energy. One simple way to represent this transformation is shown below.

Electrical energy → Sound energy

If the radio is powered by a battery, however, two energy transformations take place, one after the other. This is because the battery contains certain chemicals that react with one another when the circuit is completed by turning on the switch. The reaction produces electrical energy. In this case, the series of energy transformations is:

Chemical potential energy → Electrical energy → Sound energy

The energy transformations involved in switching on an incandescent light

Generally more than one form of energy is produced during an energy transformation. For example, when an incandescent light globe is turned on, the globe gets hot. This means that the some of the electrical energy has been transformed into light energy and some into heat energy.

We can represent this by the following flow chart.

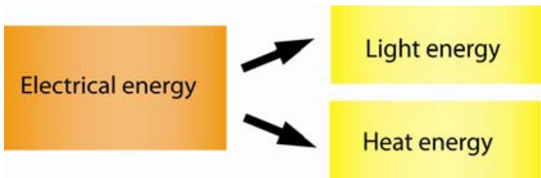


Figure 8

The energy transformations involved in lighting a Bunsen burner

Figure 9 A lit Bunsen burner (air-hole open)

The chemical reaction

The main gas present in the gas that burns is methane.

When the Bunsen burner is lit, the following chemical reaction is the main reaction that takes place:

methane + oxygen → carbon dioxide + water + energy

- The methane and the oxygen (which comes from the air), are called reactants. **Reactants** are the chemical species that react and change during the reaction. They are listed ***before*** the arrow.
- The carbon dioxide and water are called products. **Products** are the new chemical species produced in the reaction. They are listed ***after*** the arrow.

NOTE: The energy 'produced' in the reaction is the result of an energy transformation and is not classified as a product.

This is summarised below:

methane + oxygen	→	carbon dioxide + water	+ energy
REACTANTS	ARROW	PRODUCTS	

Because a flame is produced when the gas burns, this is classified as a **combustion reaction**.

The energy transformations

The energy transformations that occur in this combustion reaction are more complex than those that occur when you switch on an incandescent light. When the gas burns, the following forms of energy are all produced:

- Light energy (seen as the flame)
- Heat energy (felt as the warmth of the flame)
- Sound energy (the sound of the flame)

We can represent this by the following flow chart (Figure 10).

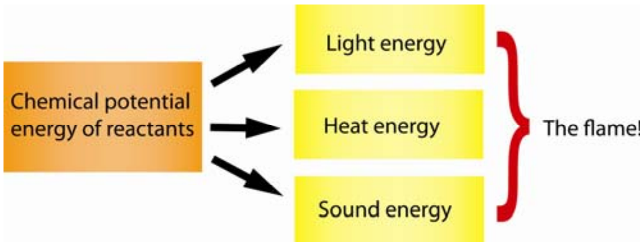


Figure 10

Another way to represent this energy transformation, called a **Sankey diagram**, uses different arrow widths to show that the chemical potential energy of the reactants is mostly transformed into heat energy. This is shown in Figure 11.

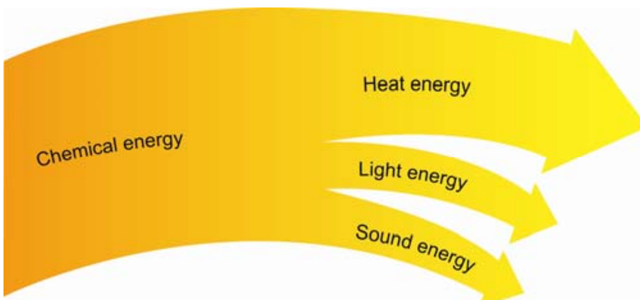


Figure 11

The Law of Conservation of Energy

When energy is transformed from one form to another, it is neither created nor destroyed. It has simply changed form. This is known as the **Law of Conservation of Energy**.

What do you think?

How does the Sankey diagram in Figure 11 convey the idea that the total amount of energy does not change when energy transformations take place?

____

____

Can you suggest another way energy transformations can be represented that also shows that energy has been conserved? Show your idea in the space below.

MOVING ENERGY FROM ONE PLACE TO ANOTHER

Energy **transfer** is the passing along of a particular form of energy from one place to another. This is shown in the following examples.

Transferring heat energy

When a metal saucepan containing water is placed on a hot stove, very soon the water and saucepan lid are hot like the base of the saucepan. This is because the heat energy of the flame or heating element is transferred to the water and to the saucepan lid.

Heat energy can be transferred from one place to another in three ways:

- **Conduction** – heat energy is transferred through a material or between materials due to contact at the particle level. This happened in the saucepan.
- **Convection** – liquids or gases gain heat energy and then move from one place to another.
- **Radiation** – objects give off radiation in the form of infra-red radiation (see page 6).

The last two are the reason your skin can sense the saucepan is hot without touching it.

Transferring electrical energy

When an electrical circuit is complete, electrical energy is transferred from the energy source by the metal wires to the components in the circuit, such as a globe.

Did you know?

Metals are all classified as good conductors of heat and electricity. This means metals transfer heat energy and electrical energy well. But they do vary in their ability to transfer energy. The three metals that are the best electrical conductors are gold, silver and copper. This is why many electronic circuits have their wiring made from one or more of these metals. Figure 12 shows an electronic circuit in which gold is used.

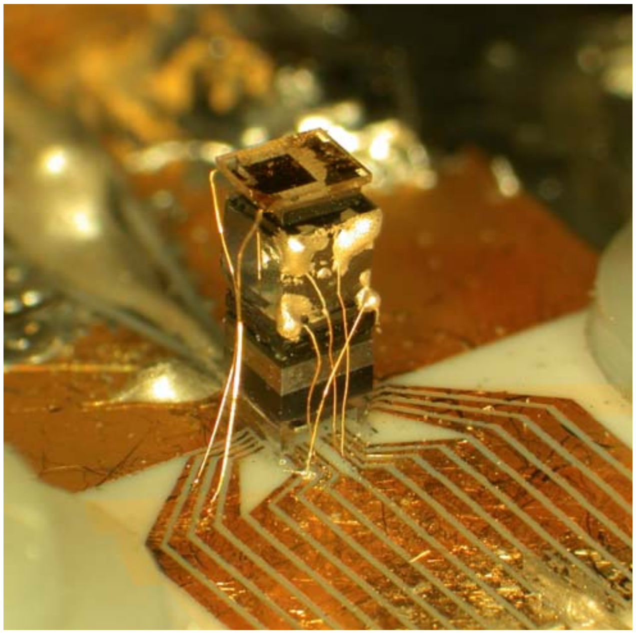


Figure 12

PRACTICAL ACTIVITY 2: WHAT ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS ARE HAPPENING HERE?

Group members: ____ **Date:** ________

Introduction

In this activity you will move about from one station to another and explore what is there. In each case you will need to decide what energy transformations and energy transfers you think have occurred.

At Station E you will be using a commercial battery. A commercial battery is one you can purchase in a shop. Strictly speaking, a single 1.5 V battery should be called a cell. A 3 V battery consists of two 1.5 V cells joined together so they can deliver a larger voltage. (This is rather like the difference between solar cells and solar panels.)

Cells – the inside story

Although it surprises many people, cells just contain chemicals. In fact, the main two chemicals in them are one chemical that releases electrons and another chemical that takes in electrons. **Electrons** are extremely tiny particles that have a negative charge. They are present in all substances. Amazingly, electrons can travel through metals.

Cells are very cleverly designed. The two main chemicals are kept apart inside the cell, so the electrons have to travel around the circuit between them! This electron movement can only happen if there is a complete path between the positive and negative terminals of the cell. This is shown in Figure 1.

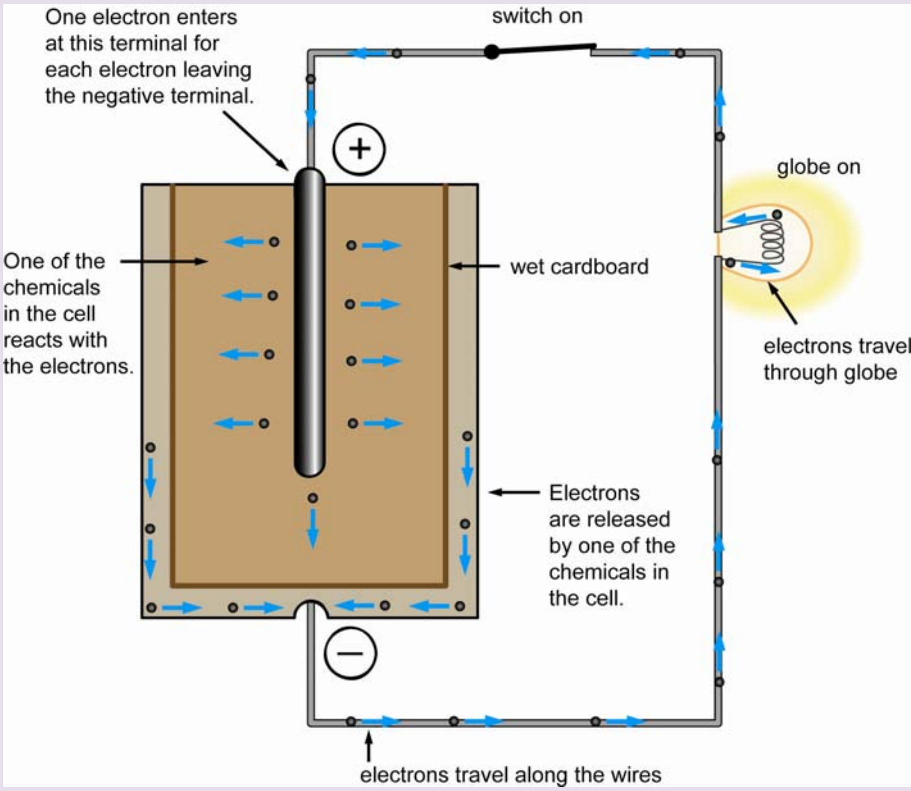


Figure 1 The net direction of movement of electrons within a cell and around a circuit. The black dots represent the electrons and the blue arrows show their net direction of movement.

Notice the electrons are all moving in the same direction. This is called a **direct current**, symbol **DC**.

This is the way that chemists view cells, because their main concern is the chemical processes occurring within the cell. (These are classified as redox reactions, which will be discussed later.)

What to do and what you discover

Station A: Light sticks

What to do at Station A
Take one of the light sticks and bend it to make it light up according to your teacher's directions.
Keep holding it. Does it get warmer or cooler?
What energy transformation(s) do you think have happened? Write your ideas in Table 1.

Table 1 Results for Station A, and what you think happened

What did you observe?	What energy transformation(s) do you think happened? Represent it (them) in some way.

Discussion questions for Station A

Figure 2

1 Figure 2 shows the kind of chemical reaction that occurs in a light stick. The reaction occurs when two certain chemicals are mixed. This phenomenon is known as **chemiluminescence.** Why do you think you have to bend the light stick to see this phenomenon?

____

2 What question do you have about light sticks or chemiluminescence? ________________________________

Station B: A chemical reaction

What to do at Station B

1 Pour 40 mL of vinegar into the 100 mL conical flask provided on the tray.

2 Add a few drops of universal indicator solution to the vinegar.

3 Take the temperature of the solution using the thermometer provided. Your teacher will show you how to use it.

4 Add a teaspoon of bicarb soda to the vinegar and stand back! Record all your observations, including what happens to the temperature of the solution, in Table 2.

When there are no more changes, pour the contents of the flask down the sink or into the container provided, and rinse the flask clean with fresh water. Leave it to dry on the paper towel or drainer provided.

What energy transformation(s) do you think have happened? Write your ideas in Table 2.

Table 2 Results for Station B, and what you think happened

Temperature changes	**What did you observe?**	**What energy transformation(s) do you think happened? Represent it (them) in some way.**
Initial temperature: ____________ During the reaction: __________________ __________________ Final temperature: _____________		

Discussion questions for Station B

Figure 3

1 Bicarb soda is often used in cooking to make cakes rise, like the ginger cake shown in Figure 3. It reacts with acidic substances in the cake mixture, producing bubbles of gas that rise up through the mixture. Its chemical formula is $NaHCO_3$ and its chemical name is sodium hydrogen carbonate. Originally it was called sodium bicarbonate. What do you think the gas is? ___________

2 What do you think is one energy transfer that happened when this reaction took place?

____

3 What question(s) do you have about this chemical reaction or the temperature changes you observed?

____

____

Station C: Dissolving some crystals

Information about Station C

Did you know that most solid crystals have water molecules inside them?

If the crystals are warmed gently for a little while in an oven, the water molecules will migrate out of them and form steam.

Interestingly, this can change the colour of the crystals. For example, 'normal' copper sulfate is blue, as shown in Figure 4.

The chemical formula of these crystals is $CuSO_4.5H_2O$.

This tells us that for each copper atom present, there are five water molecules embedded in the crystal.

When the water molecules are driven out, the crystals turn white! It is then known as 'anhydrous copper sulfate (or, more strictly, anhydrous copper(II) sulfate).

At this station you will see what happens when you mix the white crystals with water, and measure the temperature changes that occur.

Figure 4

What to do at Station C

1 Pour 50 mL water into the 100 mL beaker provided on the tray

2 Take the temperature of the water using the thermometer provided. Your teacher will show you how to use it.

3 Add a spatula-full of anhydrous copper sulfate to the water and stir. Record all your observations, including what happens to the temperature of the solution, in Table 3.

When there are no more changes, pour the contents of the beaker into the container provided (NOT DOWN THE SINK!). Then rinse the beaker clean with fresh water, pouring the rinse water into the container as well. Leave it to dry on the paper towel or drainer provided.

What energy transformation(s) do you think have happened? Write your ideas in Table 3.

Table 3 Results for Station C, and what you think happened

Temperature changes	**What did you observe?**	**What energy transformation(s) do you think happened? Represent it (them) in some way.**
Initial temperature: ____________ During the dissolving process: __________________ Final temperature: _____________		

Discussion questions for Station C

1 How might the colour change be explained? ____

2 What is one energy transfer you think happened? ____

3 What question (s) do you have about dissolving this compound or the temperature changes you observed?

____

Station D: A chemical cell

Information about Station D

You will use the STELR multimeter shown in Figure 5 to measure voltage produced by this chemical cell. The cell, as you can see, consists of two different metal strips placed in a salt solution. This is like one of the earliest chemical cells ever used.

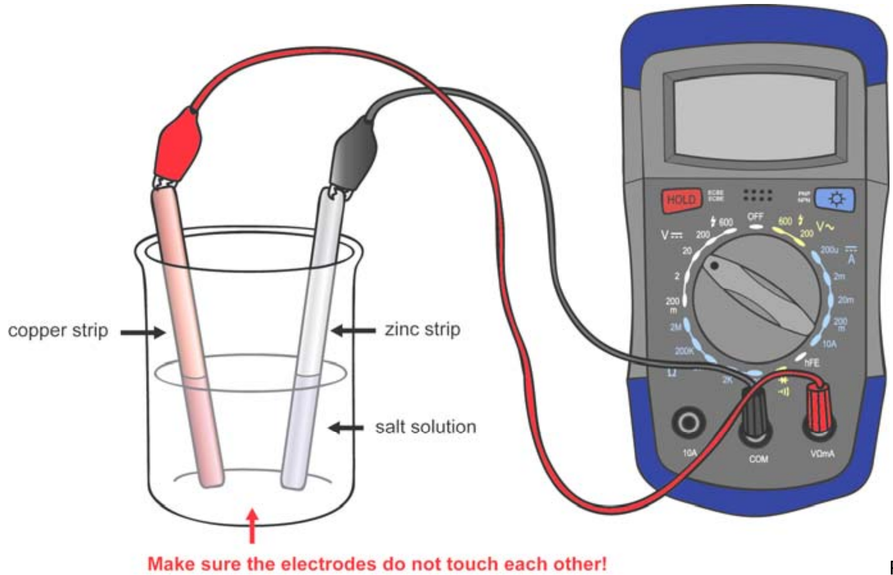


Figure 5

What to do at Station D

1 Put on the safety glasses.

2 Wipe the metal strips with the paper towel provided, then rub them with emery paper to clean their surface.

3 Measure out 60 mL of fresh salt solution into the measuring cylinder. Pour it into the 100 mL beaker then insert the metal strips as shown in Figure 5.

4 Use the leads to connect the metal strips to the multimeter, as shown in Figure 3. Rotate the dial on the multimeter to the 20V (20 volts) mark. Does the display show a reading? If not, turn the dial to 2 V. Does it show a reading now? If not, turn it to 200 m (which means 0.2 volts). If a reading shows now, you know that the cell is working. TURN OFF the multimeter. Record the voltage reading in Table 4.

5 Are there any changes in the solution as the chemical runs? Record your observations in Table 4.

When you have finished this activity, take the metal strips out of the salt solution and leave them on the paper towel. Tip the salt solution down the sink and rinse out the beaker. Leave it to drain on the paper towel. Remove the safety glasses and leave them for the next group.

What energy transformation(s) and what is one energy transfer you think has happened? Write your ideas in Table 3.

Table 4 Results for Station D, and what you think happened

Was there any evidence that the cell was working? If so, what was the voltage?	What energy transformation(s) do you think happened? Represent them in some way.	What is one energy transfer you think happened?

Discussion question for Station D

What question(s) do you have about this chemical cell?

____

Station E: Electrolysis

Information about Station E

As stated on page 33, commercial cells contain special chemicals that react with one another to produce an electric current when the cell forms part of an electrical circuit.

At this station you will use the electrical energy delivered by a STELR battery to force water to start splitting up into its two elements - hydrogen and oxygen. The splitting up of a substance using electricity is known as **electrolysis**. The circuit you will use is shown in Figure 6.

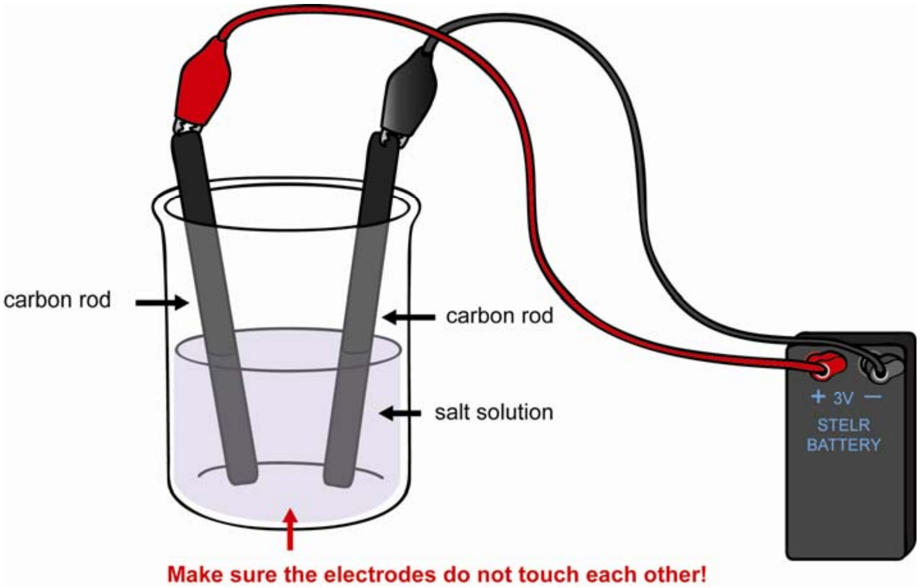


Figure 6

SAFETY WARNING!

The chemicals in commercial cells are dangerous, so they are sealed in to prevent them leaking.

NEVER TRY TO OPEN ONE!

What to do at Station E

Connect the terminals of the STELR battery or another 3 V battery to the carbon rods that are sitting in the salt solution, as shown in Figure 6. What changes happen in the water? Record your observations in Table 5.

When you have seen the changes occurring in the water, disconnect the battery and leave the equipment as you found it.

What energy transformation(s) do you think has happened? Write your ideas in Table 5.

Table 5 Results for Station E, and what you think happened

What did you observe?	What energy transformation(s) do you think happened? Represent it (them) in some way.

Discussion questions for Station E

1 Identify one example of an energy transfer that occurred when you used this equipment.

____

2 Did it surprise you to learn that the batteries you buy to run your mobile phone and so on just contain chemicals? __________

3 Why shouldn't you open cells or batteries up, or touch them if they leak?

____

4 How might the electrolysis of water be used?

____

5 What questions do you have about electrolysis?

____

____

Station F: An oil burner

Information about Station F

Ceramic oil burners are often used as a safe way to produce a mist of aromatic oils to make a room smell fragrant. A few drops of an essential oil or aromatherapy oil are placed on top of some water in a shallow bowl. A tea-light candle is burnt underneath this, which gently warms the water and causes some of the oil to evaporate into the room.

Figure 7 Ceramic oil burners come in an incredible variety of shapes and colours. Many are highly decorated.

Source: http://upload.wikimedia.org/wikipedia/commons/c/c3/Aromatas.JPG **Accessed:** 23 February, 2011

What to do at Station F

1 Check there is still water and oil in the bowl of the burner. If not, add some more, remembering to seal the oil bottle as soon as you have finished extracting a few drops.

2 Light the candle and wait until you can smell the oil. Record all your observations in Table 6.

When you have smelled the oil, blow out the candle and leave the burner as you found it.

What energy transformations do you think have happened? Write your ideas in Table 6.

Table 6 Results for Station E, and what you think happened

What did you observe?	What energy transformations do you think happened? Represent them in some way.
The candle:	
The oil:	

Discussion questions for Station F

1 Identify two examples of an energy transfer that occurred when you used the oil burner.

____

____

2 Can you suggest why the oil is placed on water rather than heated directly?

____

____

Find out more!

These organisms exhibit a special form of chemiluminesence called bioluminescence. Find out more about this phenomenon. Why have the organisms evolved to the ability to produce their own light? Might global warming affect this?

Figure 8 Thee common glow worm

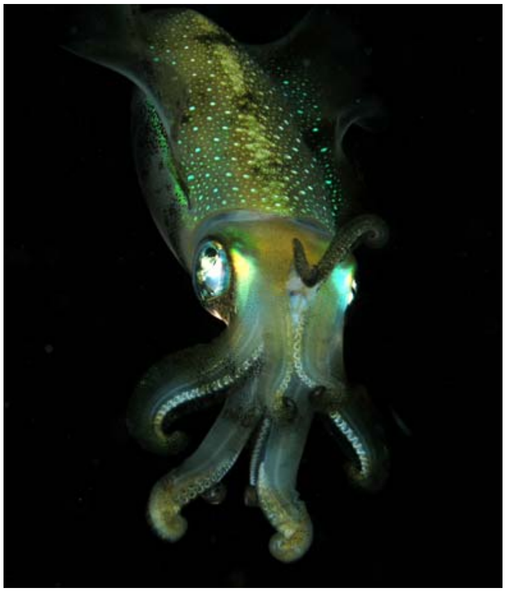


Figure 9 One of the many species of bioluminescent squid

6 HOW DO HYDROELECTRIC POWER STATIONS WORK?

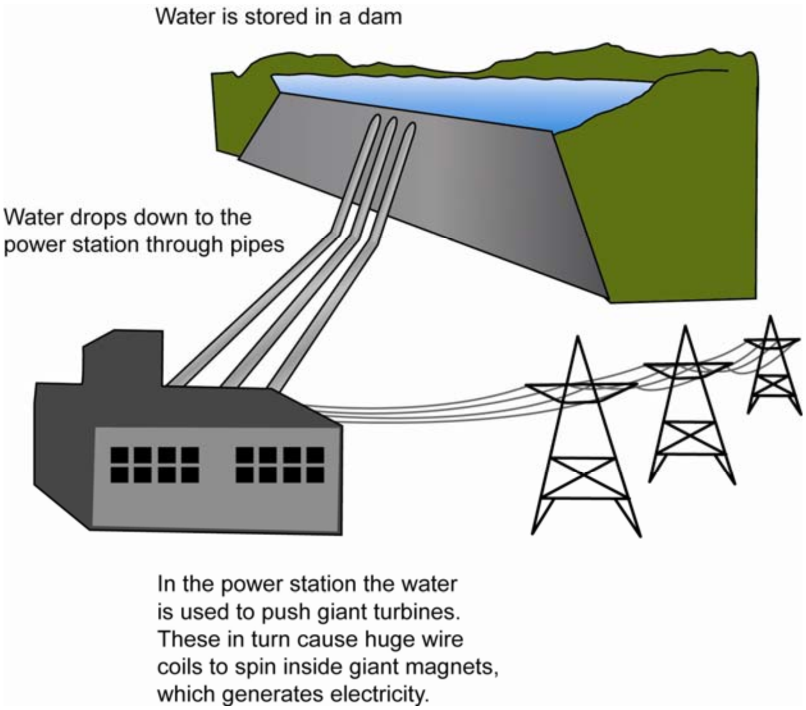


Figure 1 A hydroelectric power station (*Also see the photograph on page 27.)

A hydroelectric power station is another example of energy transformations and energy transfers in action. As can be seen in the diagram, water is stored in a dam that is located high above the power station. When the valves are open, the water rushes down pipes that take it into the power station. There it pushes the blades of a turbine, causing them to spin.

What is a turbine?

A **turbine** is like a giant fan. It is a machine that consists of a set of blades, 'scoops' or rotors that spin very fast when pushed by fast moving air, water or steam.

In hydroelectric power stations, the turbine is pushed around by fast-moving water that has flowed down from a dam. One kind of turbine is made up of 'scoops', which 'catch' the water. This is known as a Pelton turbine.

An example of Pelton turbines in a hydroelectric power station is shown in Figure 2. (In this photograph the turbines have been temporarily shut down for maintenance.) Notice how the turbines are connected to a driving shaft. When they spin, they make it spin fast as well.

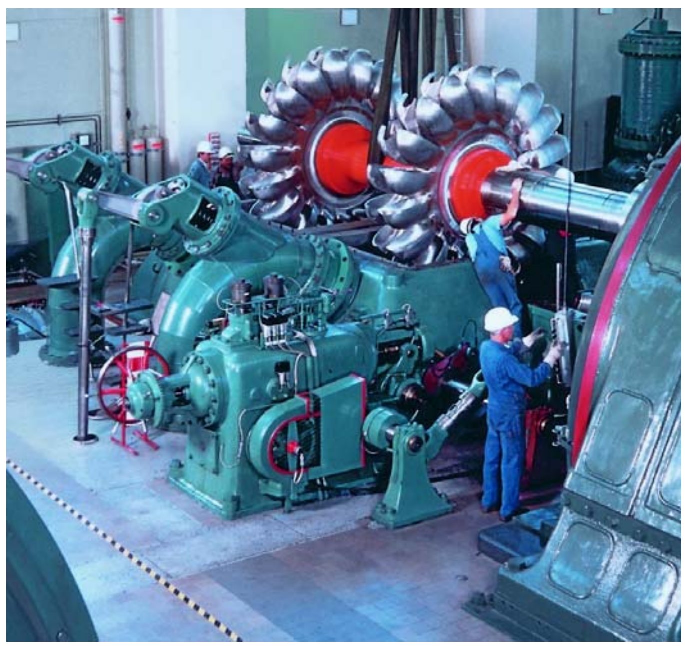


Figure 2 Inside a hydroelectric power station that uses Pelton turbines

What happens next?

The driving shaft in turn causes a magnet to spin very fast inside a wire coil, or a wire coil to spin very rapidly around a giant magnet. This results in an electric current being generated (produced) within the coiled wire. The machine that consists of the magnet and wire coil is called a **generator**. The generator is on the far right of Figure 2.

The electric current produced then passes through a device called a transformer, in which its voltage is greatly increased. It then is transmitted via an **electricity grid** (network of electric wires) to the places where the electricity is to be used.

What energy transformations and energy transfers take place?

From the dam to the power station

The water in the dam possesses gravitational potential energy. When the water rushes down the pipes, the gravitational potential energy of the water is transformed into kinetic energy.

At the power station

By the time the water reaches the turbine, it is moving at a high speed. When the water hits the blades of the turbine, it gives them a strong push, causing them to spin very fast. In the process, most of the kinetic energy of the water is transformed into the mechanical energy of the turbine. The water then flows through pipes to a lower part of the river.

The spinning turbine is connected to the generator, so its mechanical energy is transferred to the wire coils of the generator, which spin as a result. This causes an electric current to be produced within the wires. Hence within the generator, mechanical energy is transformed into electrical energy. The electrical energy is finally transferred to the consumers via the grid.

Discussion questions

1 Explain the difference between energy and a force, using the example of the dam water in a hydroelectric power station to help illustrate their meaning.

____

____

2 The word ‘kinetic’ comes from the Greek word *kinetikos*, meaning to move. Explain the meaning of the term ‘kinetic energy’.

____

3 From the information provided, draw a diagram or flow chart to show the energy transformations that take place in a hydroelectric power station.

Challenge questions

4 Why do you suppose that not all the kinetic energy of the flowing water is transformed into the mechanical energy of the turbine? What do you think happens to the remaining kinetic energy?

____

____

____

5 Many people think of hydroelectricity as a ‘clean’ and ‘green’ source of electrical power. However, the establishment of hydroelectric power stations remains controversial. Why might people oppose their construction?

____

FUELS

How do biofuels, such as bioethanol produced from wheat stubble, compare with fossil fuels, such as petrol and diesel, as fuels for driving vehicles?

BIG IDEAS

How did coal and oil form?

What's the difference between fossil fuels and biofuels?

Are biofuels the answer to global warming?

What are some ways chemists classify chemical reactions?

7 WHAT KINDS OF FUELS ARE THERE?

What is a fuel?

A **fuel** is a substance that burns at a fast but controllable rate. The fuels we use today are usually mixtures of many different compounds. These compounds are generally composed of molecules that contain carbon and hydrogen atoms only, or carbon, hydrogen and oxygen atoms. (Some contain other elements, such as sulfur.)

When these fuels burn in air, the main reaction occurring is:

fuel + oxygen → carbon dioxide + water + energy

Fuels like these do not burn unless oxygen or air is present. (Air is about 20 % oxygen.) They also need a spark to start the reaction off – that is, to ignite the fuel. This is shown in Figure 1.

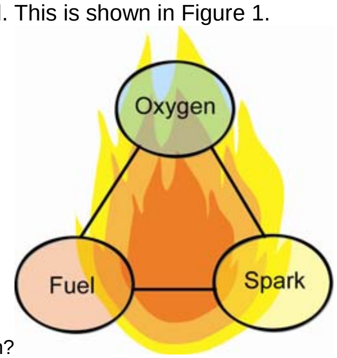


Figure 1 What is needed for a fuel to burn?

Why do we need fuels?

The heat energy produced when a fuel burns can be used for a range of important purposes. These include:

- Warming buildings
- Cooking food
- Recycling materials
- Running machinery
- Generating electricity
- Manufacturing processes, such as making glass and cement
- Extracting metals from their ores, such as aluminium from aluminium ore
- 'Driving' the engines of motor vehicles, aircraft, ships, and so on
- Welding metals together to construct buildings, bridges, vehicles, ships, and so on
- Incinerating medical waste to destroy harmful bacteria

No wonder we need fuels!

Figure 2 Manufacturing glass. Sand and limestone are two of the main raw materials used to make glass. These and the other raw materials required for the particular type of glass being manufactured are heated together in a furnace to over 1000 ºC. The fuel burnt to produce this heat energy is usually natural gas.

Figure 3 Opening an inspection door in a furnace (called a boiler) at Loy Yang Power Station in Victoria. The fuel being burnt is coal. The furnaces in which the coal is burnt are almost as high as a 12-storey building!

PHOTO CREDIT: Loy Yang Power Station

> **Note**
> **Our discussion will be confined to fuels that burn. It will not include nuclear fuels, which are a very different kind of fuel. In their case nuclear reactions produce heat energy.**

Where do fuels come from?

The fuels we use today ultimately come from plants and other living organisms. Some were produced by and from organisms that lived a very long time ago. Others are being produced right now. We will discuss ancient and newly formed fuels next.

Fossil fuels

The coal, oil and natural gas we use today were produced from organisms that lived millions of years ago. These organisms included tiny aquatic organisms and plants that lived in swampy regions and even in ancient forests, which over time were covered with layer after layer of wet sediments (mud).

These layers of sediments pressed down on them. Over time the sediments turned into rock. With the pressure and heat at those depths, and the action of anaerobic bacteria (bacteria that live without oxygen), the remains of the organisms were slowly changed into oily liquids and gas, or else into coal. What was formed depended on the actual conditions and type of organisms.

How oils and natural gas formed

You no doubt have seen images of what happens when crude oil spills into a marine environment. But do you know how crude oil was produced in the first place?

When aquatic organisms died near the bottom of stagnant bodies of water or the bottom of a deep lake or marine basin and were rapidly covered with mud, they were slowly changed into natural gas, oils and tars. The formation of these substances started up to 200 million years ago. See Figures 4 and 5.

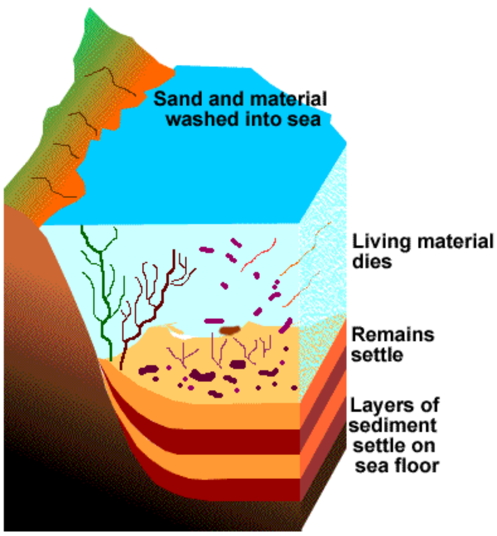


Figure 4 How the formation of oil and natural gas under the sea began, millions of years ago.

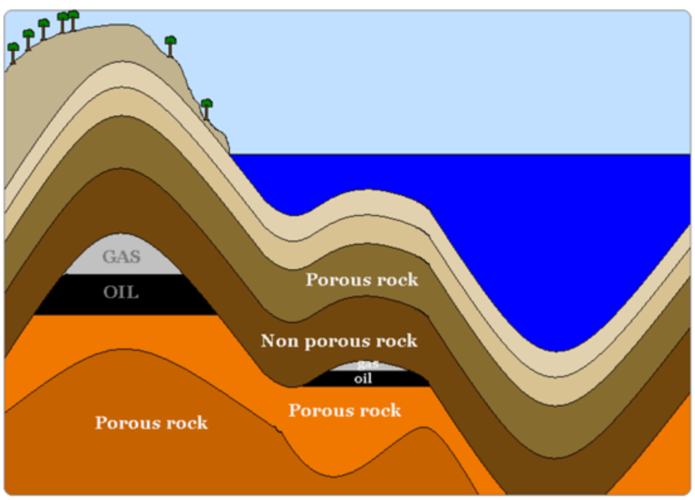


Figure 5 The organisms were slowly covered with sediments and subjected to heat and pressure and the action of anaerobic bacteria. Over time, this changed them into oil and gas. The oil and gas seeped through porous rock (rock that has small spaces through which substances can migrate), but could not seep through non-porous rock. As a result they collected in various 'pockets' under the non-porous rock.

How coal is formed

Coal is a complex mixture of carbon, water and a number of other substances. Figure 5 shows the different stages of coal formation.

Younger coal is quite soft and wet and is called **peat** (Figure 6). Because its water content is relatively high, peat does not burn well. Older coal contains less water than peat, and is harder. The coal formed over a longer time is called lignite, or **brown coal** (Figure 7). The oldest coal is commonly known as **black coal** (Figure 8). It is harder again. Since it contains even less water, it burns best.

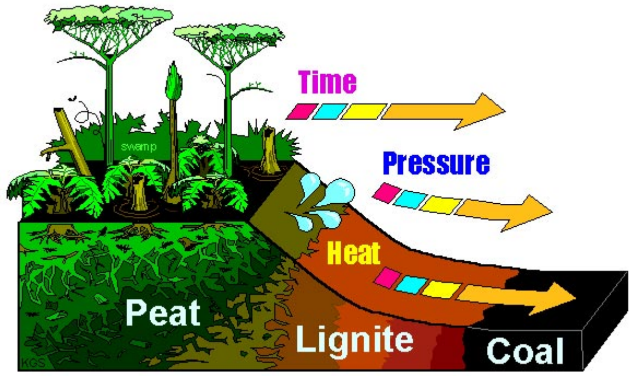


Figure 5 A diagram illustrating the process of coal formation. The label 'coal' refers to black coal.

Figure 6 Peat. Notice how wet it is, and how close it is to the surface.

Figure 7 These mining engineers are standing on a bed of brown coal located in the Latrobe Valley, Victoria. In Australia brown coal is quite close to the surface, which makes it much easier to mine. All the miners need to do is to dig a giant hole and scoop it out. (This is known as open-cut mining.)

PHOTO CREDIT: Loy Yang Power Station

Figure 8 A sample of black coal. There are deposits of black coal all over Australia, but about 97 % of the black coal we use or export comes from New South Wales and Queensland.

Australia has vast deposits of brown coal and black coal. The brown coal found in Australia is up to about 50 millions of years old while our black coal is on average about 250 million years old. A high proportion of this coal is used as a fuel to generate electricity (see Figure 3).

Because of their ancient origins, coal, crude oil and natural gas are termed **fossil fuels.** Interestingly, small fossils are often found in coal. Because they took so long to form, and are in limited supply, they are a **non-renewable** energy resource.

How amazing is this?

In one coal sample, workers found the remains of an ancient snake that was bigger than a bus! Visit this website to learn more.

http://news.nationalgeographic.com/news/2009/02/090204-biggest-snake-fossil.html

Biofuels

The fuels we use today that come from organisms that are living today or have recently been harvested, are called **biofuels.** Because we can keep producing them, biofuels are classified as **renewable** energy resources.

Table 1 lists some common biofuels and how they are produced.

Table 1 Examples of biofuels

Biofuel	How is it produced?
Biogas	Biogas, which mostly is methane gas, is produced by the action of bacteria on rotting animal manure, human sewage and rotting garbage. The source is sealed so the biogas cannot escape. It is collected through a system of pipes. Before it is used it is treated to remove foul-smelling gases that are present in small amounts.
Bioethanol	One way in which bioethanol is by the fermentation of sugars present in sugar cane or in the waste products from a sugar refinery. It also can be obtained by treating grains such as corn and wheat, wheat stubble, etc.
Biodiesel*	Biodiesel is produced by the chemical treatment of oils obtained from plants, microalgae and other organisms. The treatment includes a reaction with an alcohol, usually methanol.

Note: *The diesel that comes from crude oil is increasingly being called petrodiesel to distinguish it from biodiesel.

It's a fact!

Before people discovered our vast fossil fuel reserves beneath the ground, they mostly relied on biofuels to obtain the heat and light they needed. The most popular biofuel for heating was wood. Huge areas of forest were cut down to provide wood for burning. One popular biofuel for lighting lamps was whale oil. So it might be said that switching to the use of fossil fuels saved the lives of thousands of whales as well as of millions of trees, not to mention the lives of a huge variety of species that lived in the forest habitats. However, burning fossil fuels has its own drawbacks, as you will learn on the next page.

What energy transformations take place when fuels are produced and used?

As you have just learned, fossil fuels and biofuels ultimately come from living organisms. Most of these organisms depended on photosynthesis to produce the glucose they needed to survive. The main difference between fossil fuels and biofuels is the time it took to produce the fuels. In the case of fossil fuels, the process of creating the fuel from the organisms that first used the energy from the Sun, took millions of years.

The overall energy transformations involved in using either kind of fuel to drive a vehicle shown in Figure 9.

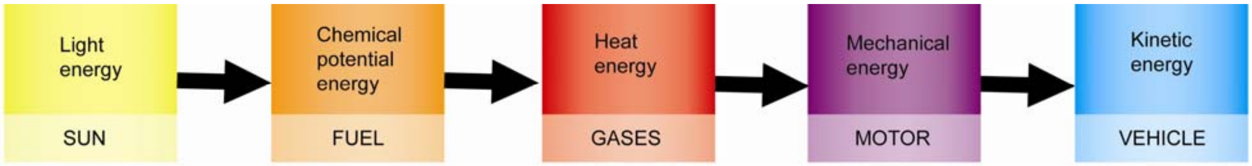


Figure 9 The main energy transformations involved in producing and using a fuel that is used for driving a vehicle

This flow chart shows that all the energy we obtain from fuels, whether ancient or new, originally comes from the Sun. So when we burn natural gas, for example, we are really using light energy from the Sun that shone on the Earth millions of years ago!

What are some of the advantages and disadvantages of fossil fuels?

Some of these are listed in Table 2.

Table 2 Some advantages and disadvantages of fossil fuels

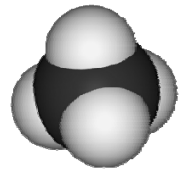
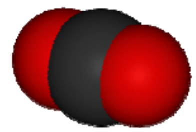
Advantages	Disadvantages
1 They are 'energy-rich' fuels. That is, you obtain a large amount of energy per kilogram of the fuel. Moreover, not much energy is needed to process fossil fuels before they are used.	1 When they burn, they produce a large amount of greenhouse gases (mainly carbon dioxide and steam). So they contribute to the problem of global warming. 2 Some also produce other harmful substances when they are purified or when they are burnt. These include acidic gases that dissolve in the moisture in the air and cause rain and snow to be acidic. When acid rain and acid snow fall down onto waterways and soils, they kill many plants, fish and other organisms. They can destroy whole ecosystems. 3 Coal is wet. A lot of the energy that might be obtained from burning coal is wasted in evaporating the water. 4 Because they are all energy-rich, there is always a high danger of fire and explosions when they are extracted, processed, transported and stored. If a coal bed catches alight, it can take months to put the fire out.
2 They are abundant. In Australia, for example, we have vast quantities of coal that should last for hundreds more years. This means the coal can be used to generate electricity on a large scale at relatively low cost.	5 They are still a non-renewable energy resource, so they will eventually run out.
3 Crude oil and natural gas flow easily so can be piped to the nearest refinery to be processed. In the case of natural gas, it can be piped directly from where it is purified to a gas-fired power station.	6 There is a great danger of oil spills, which can damage the environment and kill or harm many living things. Crude oil is toxic and contains carcinogenic (cancer-causing) compounds. There also is a risk of toxic gas leakages.
4 Because crude oil and natural gas are mixtures, they can be separated into different products that suit particular purposes. For example, kerosene is a blend that suits aircraft.	7 There are many other uses for the chemicals present in crude oil and natural gas. They are the raw materials used to produce plastics, dyes, pharmaceuticals, and so on. So burning then as a fuel means less is available to produce thousands of very useful substances.

What are some of the advantages and disadvantages of using biogas?

Biogas is probably one of the most useful and sustainable biofuels there is. Its main advantages are listed in Table 3.

Table 3 The main advantages of using biogas

Advantage	Example
1 It is a renewable fuel that can be collected on a small scale, such as in small rural communities and on individual farms, and on a larger scale, such as from landfill sites and sewage treatment plants in large cities. This means it does not have to be transported large distances and it can be collected and used by even the poorest communities. Figure 10 A domestic biogas collection system in Africa	

Advantage	Example
2 It makes use of waste. It does not require land that might be used to grow crops or cutting down precious rainforests. Therefore poor communities are not deprived of essential food, and the rich ecosystems within rainforests are not endangered. Figure 11 Destroying a rainforest to grow food or products such as palm oil, which is used in the manufacture of cosmetics, processed foods and biodiesel.	
3 Biogas is emitted by rotting animal wastes and rubbish, whether we use it or not. One problem with this is that it smells foul. More importantly, it means methane is released into the air. The methane molecule is about 20 times more potent at ‘trapping’ heat than the carbon dioxide molecule. So it is much better to burn it and produce carbon dioxide than to allow it to enter the air as it is. Therefore this helps solve the problem of global warming. A worded equation for the combustion of methane is: **methane + oxygen → carbon dioxide + water + energy** Collecting and burning biogas also reduces the risk of build-up of methane gas under buildings and roadways. Methane seeping from landfill sites, and so on, has been known to cause explosions and loss of life. Figure 12 Models of the methane molecule and the carbon dioxide molecule.	 Methane CH_4  Carbon dioxide CO_2 For each molecule of methane burnt, one molecule of carbon dioxide and two molecules of water are produced. (See Figure 2 page 66.)
4 Biogas is a gas so can easily be piped to where it is burnt.	
5 The energy produced by burning biogas can be used for heating or for generating electricity, or both. It even can be used as a transport fuel to drive buses and cars. Figure 13 A biogas cogeneration plant – that is, a plant where the biogas is used to generate electricity and heat at the same time.	

What are some disadvantages of using biogas?

Disadvantages of biogas include:

- It can explode if it builds up in a closed space and there is a spark, so it must be collected very carefully. Pipes and storage tanks must be constantly checked to ensure the gas cannot leak out.
- It is not suitable as a large-scale energy resource for big cities or a whole state. Typically the electricity generated by burning the biogas collected at a large sewage treatment plant or a landfill site might be able to power about 1000 homes.

Find out more!

Visit the website: http://www.drylandfarming.org/FB/Biogas4.html for case studies of small communities in China and Africa that collect and use biogas.

What are some of the advantages and disadvantages of bioethanol?

Bioethanol, commonly known as alcohol, has the chemical formula C_2H_5OH.

From Figure 14 and its chemical formula, it can be seen that the molecule contains two carbon atoms, a total of six hydrogen atoms and one oxygen atom.

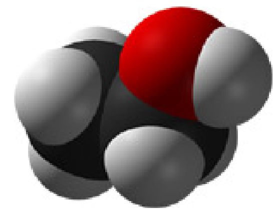


Figure 14 A model of the ethanol molecule

You will investigate the production of bioethanol later.

Table 4 lists some of the main advantages and disadvantages of bioethanol.

Table 4 Some advantages and disadvantages of bioethanol

Advantages	Disadvantages
1 When pure bioethanol is burnt, it burns 'cleanly'. That is, no smoke is produced. The main products are carbon dioxide and water. (Small amounts of other substances also are produced.)	1 Bioethanol absorbs moisture out of the air if it is not properly sealed from it, which means it is difficult to keep it pure. The presence of water also affects the amount of energy obtained per kilogram of this fuel. 2 It still produces greenhouse gases when it burns. Moreover, it is not as 'energy-rich' as fossil fuels. Therefore, when compared with them, it produces a greater amount of greenhouse gases than fossil fuels for a given amount of energy produced when they are burnt.
2 Bioethanol can be blended with petrol in different proportions to suit different vehicles. This reduces the consumption of fossil fuels.	3 While oils such as those present in petrol help protect engine parts of motor vehicles from corrosion, the presence of bioethanol, especially if it also contains water, can be a problem. In addition, bioethanol vaporises more easily than petrol and its vapours can cause problems. For this reason, for most vehicles in Australia, it is generally advisable to use blends that contain less than 10 per cent bioethanol.
3 Bioethanol can be produced from wastes, such as those produced in sugar refineries.	4 Transporting wastes to where they can be treated and the impure bioethanol to where it is purified, consumes more fuel and produces more greenhouse gases than may be justified in many cases. In general it has been found that it takes more energy to produce, purify and transport each kilogram of bioethanol than is obtained from it when it is burnt as a fuel.* 5 The production of bioethanol consumes a lot of water.
4 Bioethanol can be produced from a wide range of plant material.	6 There are other important uses of bioethanol besides as a transport fuel. It is used to manufacture a wide range of useful chemicals, including solvent cleaners. Burning it as a fuel means less is available for producing a wide range of other useful substances. 7 No country in the world, including Australia, has enough arable land to grow the amount of crops that would be needed if we were to replace fossil fuels with bioethanol, even if none of the land was used for food production. Therefore only relatively small amounts can ever be produced.

Note: * Earlier ethanol refineries, places where bioethanol was purified by distillation, consumed more energy than could be obtained back from the final product. However, special distillation techniques have been developed to overcome this problem.

You will investigate the production of bioethanol later.

What are some of the advantages and disadvantages of biodiesel?

Biodiesel is a mixture of molecules, most of which belong to a family of organic compounds called fatty acid methyl esters. In the industry this is abbreviated to FAME.

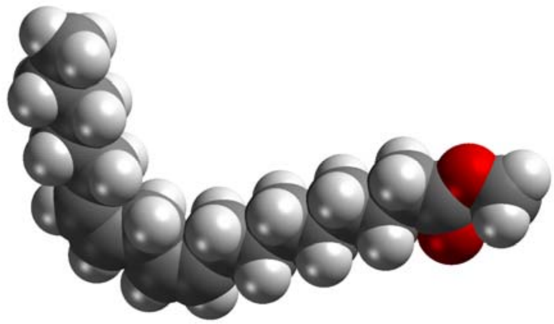


Figure 15 This is a model of a typical fatty acid methyl ester (FAME) molecule.

Not all molecules present in biodiesel have a 'bend' in them like this one.

The main difference between biodiesel molecules and petrodiesel* molecules is:

- Biodiesel molecules contain two oxygen atoms close to one end (shown here as red spheres).
- Petrodiesel* molecules are chains of carbon and hydrogen atoms only.

*Remember petrodiesel is another name for 'normal' diesel, which comes from refining crude oil.

Biodiesel is produced by reacting vegetable oils or fats with an alcohol. Glycerol also is produced in this reaction. When the alcohol used is methanol (commonly called methyl alcohol), the biodiesel produced is in the form of fatty acid methyl esters. The reaction is called a **transesterification reaction**. A simplified worded equation for the reaction is:

vegetable oil + alcohol → biodiesel + glycerol

Table 5 Some advantages and disadvantages of biodiesel

Advantages	Disadvantages
1 As a fuel for vehicles, biodiesel performs just as well as petrodiesel when used at warm temperatures. It performs much better than a vegetable oil. 2 Engines last longer when biodiesel is used rather than petrodiesel.	1 Biodiesel does not perform as well as petrodiesel when it is cold. It becomes too viscous to flow properly to the combustion chamber in the engine. 2 Biodiesel can adversely affect rubber parts. 3 Biodiesel is more likely to attract moisture than petrodiesel. This can cause problems in the performance of the fuel and its ability to flow in cold weather, and cause corrosion.
3 Burning biodiesel produces less greenhouse gases and less other pollution per kilogram than petrodiesel.	4 Where biodiesel is produced from waste fats and oils, greenhouse gases are produced when collecting and transporting them. Where biodiesel is produced from oil crops, greenhouse gases are produced when planting and harvesting the crops and transporting them to the processing plants.
4 Biodiesel is less flammable than petrodiesel, so there is less risk of fires when storing, transporting and using it.	5 Biodiesel is more difficult to ignite in the combustion chamber in an engine in cold weather than petrodiesel.
5 Biodiesel is more easily broken down and is less toxic than petrodiesel, if it is spilt and seeps into waterways, soils, and so on.	6 Biodiesel cannot be transported via pipelines, because it can form a gel in them and block them when it is cold. So it must be transported by truck.
6 Biodiesel can be produced from waste fats and oils.	6 Processing the wastes requires more production steps and more energy.
7 The by-product of making biodiesel is glycerol, which has many uses, including in cosmetics.	6 If too much biodiesel is produced, more glycerol would be produced than can be used. (It also is produced when soap is made.)

Discussion questions

1 Complete Table 6 about biofuels and fossil fuels.

Table 6

Feature	**Fossil fuels**	**Biofuels**
Renewable or non-renewable?		
Formed up to millions of years ago, or recently?		
Formed from organisms that are alive now or that once lived, or from non-living materials?		
What must be present for them to burn?		
When they burn, what are the two main substances produced?		
Do they produce greenhouse gases when they burn?		
What is one danger that must never be forgotten when processing, storing, transporting and using them?		
What are some examples of each kind of fuel?		
Can any of them be used to generate electricity? Which ones? Is this on a small scale or large scale?		
What are some examples of other ways they can be used?		

2 The whole 'life cycle' behind the production of a biofuel needs to be taken into account when comparing the greenhouse gases and pollution produced by using different fuels. This life cycle starts with what has to happen to produce the sugars or oils in the first place. Use some paper to draw what you think might be the 'life cycle' behind the production of biodiesel or bioethanol, and annotate your drawing.

3 ***What is your opinion?***

There are many social and environmental issues associated with the production of bioethanol and biodiesel in developing countries. What kinds of problems do you think need to be solved? How do you think these problems might be solved?

Find out more!

One source of oil for producing biodiesel that can produce far more oil per acre than can be produced by growing crops such as canola, is the oil produced by tiny microscopic organisms such as diatoms and microalgae. A great deal of research is being done on this at present. It may even be possible to use sewage treatment plants as sources of nutrients for microalgae. Use the web to find out more.

Also see the case study on microalgal biofuels on the STELR website at: http://www.stelr.org.au/bio-fuels/

and the fascinating story behind geothermal energy at http://www.stelr.org.au/geothermal-energy/

PRACTICAL ACTIVITY 3: PRODUCING BIOETHANOL

Partners: ____ **Date:** ____________

Inquiry questions

1 How is bioethanol produced from sugar?
2 Is carbon dioxide gas really produced in this reaction?
3 How much gas is produced?

Introduction

Beers, wines, ciders and other alcoholic drinks are produced by the fermentation of sugars and other carbohydrates present in various grains, or grapes and other fruits. **Fermentation** is a chemical process by which yeast organisms obtain the energy they need to live.

Yeast organisms are simple, unicellular (single-celled) micro-organisms (organisms that can only be seen under a microscope). In the classification system for living things, they belong to the kingdom of fungi.

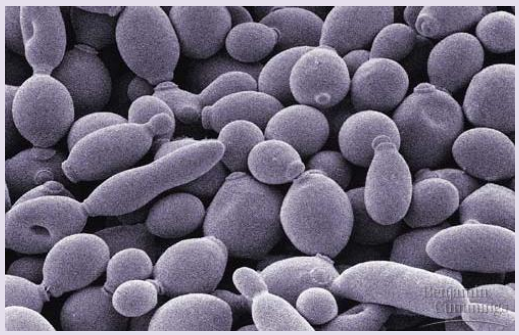


Figure 1 Yeast organisms seen through a microscope. These yeast organisms can be seen reproducing through the process of budding. Notice how they grow bigger before the bud forms, which then separates from the parent organism. The reproduction process requires energy, which is one reason why yeast organisms need energy to survive.

The fermentation reaction

The fermentation reaction can be summarised as follows:

$$\text{glucose} \xrightarrow{\text{yeast}} \text{alcohol + carbon dioxide}$$

The alcohol produced in this reaction is **ethanol**. This is called its systematic name (name according to a special naming system). It needs a systematic name because in fact there is a whole family of substances like ethanol. The family is called the alcohols. In the chemical industry this alcohol is often called ethyl alcohol. The general public usually just call it 'alcohol'.

This reaction is widespread in Nature. When ripe fruit drops on the ground, for example, wild yeast organisms present in the environment feast on the sugars in the fruit. This is why rotting fruit starts to smell alcoholic.

Killing off the yeast

For the yeast organisms, the ethanol and carbon dioxide are both waste products. If these waste products are not removed from their environment, they will poison and eventually kill the yeast organisms.

The carbon dioxide gas produced naturally bubbles out of the mixture in which fermentation is taking place, so unless the mixture is sealed in a container, this waste product does not build up. However, sparkling wines and beers are bottled and sealed before fermentation is complete. The special yeast organisms used in this process keep making carbon dioxide, but now the gas cannot escape. Instead it dissolves under pressure in the mixture. As a result, more is dissolved than would naturally dissolve at that temperature. This is why these drinks produce a lot of bubbles when the cork or lid is removed.

Whether the mixture is sealed or not, the alcohol keeps building up until the yeast organisms die. This is why there is a limit to the percentage of alcohol present in beers and wines. (It also means, of course, that unless they have been specially filtered, beers and wines contain the dead bodies of the yeast organisms that produced them!)

Bioethanol

Bioethanol is the name given to ethanol that is produced from plant material and is used as a fuel. Bioethanol can be made in several ways, but as you have learned, one way is the fermentation of the sugars present in the waste products from a sugar refinery.

In this activity you will produce some bioethanol by fermenting some sugar. Some of the class will collect the gas produced in a balloon, to see how much is produced for the amount of sugar you use. The rest of the class will make the gas bubble through water to which some universal indicator solution has been added, to test if it is carbon dioxide, as the equation states.

The only problem with this test is that other acidic gases will change the colour of universal indicator solution in the same way as carbon dioxide. There is another test for carbon dioxide that distinguishes it from all other gases. This very specific test is known as the **limewater test**. When carbon dioxide bubbles through limewater, it turns it milky, as shown in Figure 2.

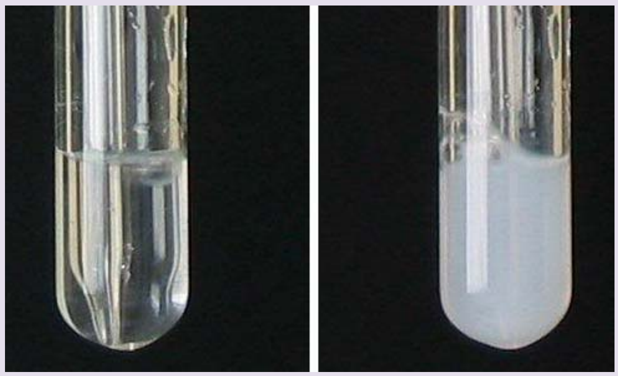


Figure 2 The limewater test. These photos show limewater before and after carbon dioxide gas has been bubbled into it. You can see why we say the limewater is turned 'milky'. The milkiness is due to the formation of tiny particles of calcium carbonate, the main constituent of chalk, sea shells, corals and marble. Calcium carbonate is white and insoluble in water.

One problem with this test is that limewater is strongly basic and is quite dangerous to handle. It is particularly harmful if it gets into your eyes. The other is that if you keep bubbling carbon dioxide into milky limewater, it goes clear again. So you have to watch carefully to make sure you don't miss the milky stage.

What you need

- 25 g white sugar (pre-weighed)
- 250 mL conical flask
- 100 mL measuring cylinder
- Glass stirring rod
- 2.5 g powdered yeast (pre-weighed)
- 500 mL beaker (to sit conical flask in)
- Thermometer

Depending on the group to which you and your partner have been allocated, you also will need the materials listed in Table 1.

Table 1 Other materials needed

Pairs in Group A	Pairs in Group B
• Balloon	• Delivery tube inserted in one-holed rubber stopper • Small dropper bottle of universal indicator solution • Test tube and test tube rack

Assessing the risks

Read the facts, imagine what could happen that might hurt someone or cause damage, and think of what you could do to prevent that problem. Hence complete Table 2.

Table 2 Risk Assessment

The facts	What might be the risks?	What precautions will we take?
1 The equipment, including the thermometer, is made of glass.		
2 Universal indicator solution can stain skin and clothes etc.		
3 Universal indicator solution and the fermentation mixture are both poisonous.		

What to do and what you discover

GROUP A

Inquiry question 1: How is bioethanol produced from sugar?
Inquiry question 3: What volume of gas is produced?

Table 3 Instructions for Group A

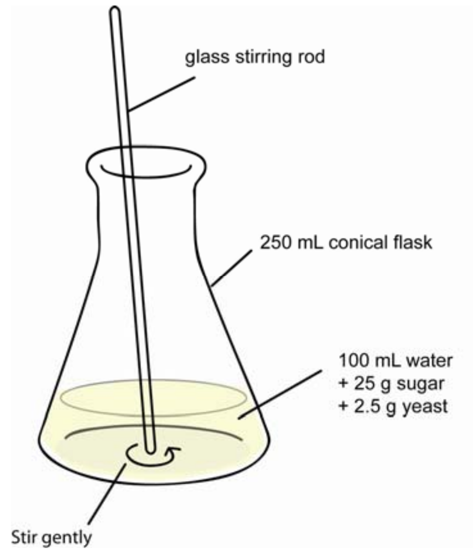
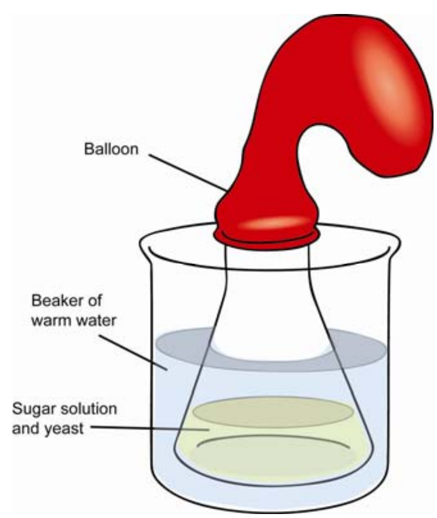
Step	What to do	How to do it
1	Tip the sugar into the conical flask.	 Figure 3 Getting the fermentation mixture ready
2	Measure out 100 mL of water using the measuring cylinder, then tip it into the flask. Gently swirl the flask until the sugar dissolves.	
3	Tip the yeast into the sugar solution and carefully mix it in using the stirring rod.	
4	Add warm water from a tap to the beaker until it is about half-full. Place the thermometer in it and measure the temperature. Add cold or hot water to this to adjust the temperature to 30 ºC. (You may need to tip some water out to make room for the extra water.)	 Figure 4 The final set-up
5	Sit the conical flask in the water, then seal it with a balloon.	
6	Observe the mixture for the rest of the lesson and over the next 3 days. Record your observations in Table 4.	
7	Discuss with your teacher how you will measure the volume of gas in the balloon, then measure and record its approximate volume.	
8	When you have removed the balloon from the flask, gently sniff the solution. Your teacher will show you how to do this safely. Then pack up according to your teacher's directions. Wash your hands with soap and water after handling the solutions.	

Table 4 Results for Group A

Time and day of observation	Observations
Day 1, when the yeast and sugar solution are first mixed	
Day 1, 30 minutes after the yeast and sugar solution are first mixed	
	What does the fermentation mixture smell like? The approximate volume of the balloon was:

GROUP B

Inquiry question1: How is bioethanol produced from sugar?
Inquiry question 2: Is carbon dioxide gas really produced in this reaction?

Table 5 Instructions for Group B

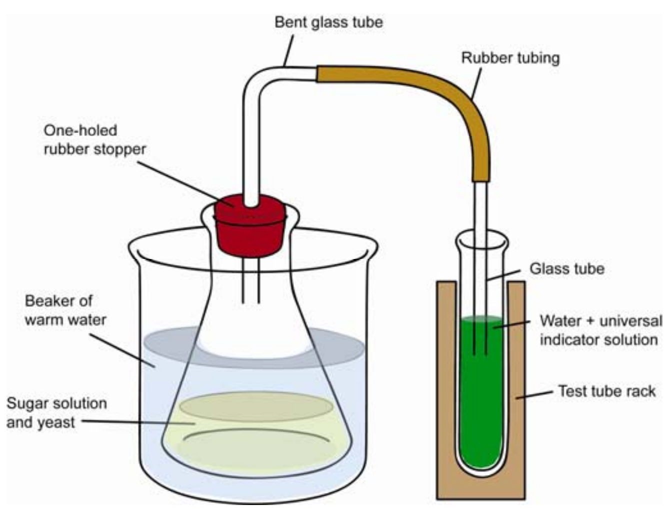
Step	What to do	How to do it
1 - 4	Follow Steps 1 to 4 in Table 3.	See Figure 3
5	Sit the test tube in the test tube rack. Half-fill the test tube with water then add 3-4 drops of universal indicator solution to the water.	 Figure 5 The final set-up
6	Carefully insert the rubber stopper into the conical flask. Sit the conical flask in the warm water, then carefully insert the other end of the tubing into the solution in the test tube, as shown in Figure 5.	
6	Observe the fermentation mixture and the solution in the test tube for the rest of the lesson and over the next 3 days. Record your observations in Table 6.	
7	Carefully remove the delivery tube from the test tube, then ease the rubber stopper out of the conical flask. Now gently sniff the solution in the conical flask. Your teacher will show you how to do this safely. Record your observations in Table 6.	
8	Pack up according to your teacher's directions. Wash your hands with soap and water after handling the solutions.	

Table 6 Results for Group B

Time and day of observation	Observations of the mixture in the flask	Colour of universal indicator	Approximate pH of solution into which gas bubbles
Day 1, when the yeast and sugar solution are first mixed			
Day 1, 30 minutes after the yeast and sugar solution are first mixed			
	What does the fermentation mixture smell like?		

Conclusions

From your results, and those of the pairs in the other group, what is your response to the inquiry questions?

Inquiry Question 1: How is bioethanol produced from sugar?

____

Inquiry Question 2: Is carbon dioxide gas really produced in this reaction? ________

Inquiry Question 3: What volume of this gas is produced? _____________ (average)

Discussion questions

1 On what evidence did you base your answer to Inquiry Question 2? Is this reasonable proof? Discuss.

____

____

2 Explain why:

a The fermentation reaction stops after a while.

____

b Yeast organisms need energy.

____

3 Suggest reasons for the following:

a An average volume of gas was calculated.

____

b The mixture of yeast and sugar solution was warmed to 30 ºC (but no higher).

____

PRACTICAL ACTIVITY 4: DISTILLING AN ETHANOL MIXTURE

Partners: ____ **Date:** ____________

Inquiry question

Can ethanol be separated from an ethanol mixture by distillation?

Introduction

Ethanol is the alcohol produced by the **fermentation** of a sugar solution. In the fermentation process, yeast organisms feed on the dissolved sugar, converting it into alcohol and carbon dioxide. When the amount of alcohol in the mixture gets too high, the yeast organisms die.

One worded equation for the fermentation reaction is:

$$\text{glucose} \xrightarrow{\text{yeast}} \text{alcohol + carbon dioxide}$$

Bioethanol is ethanol that has been produced from plant material and is used as a fuel. One way of producing it is by fermenting waste products from sugar refineries.

After fermentation, you are left with a mixture of ethanol, unfermented sugar, water and yeast. The ethanol can be separated from this mixture by a process called **distillation**. In this process, the mixture is heated. Ethanol boils at a lower temperature than water and the other substances in the mixture. Its boiling point is 78 ºC while the boiling point of pure water is 100 ºC and even higher when substances like sugar are dissolved in it.

When the temperature reaches 78 ºC the ethanol turns into a gas. The ethanol gas (and a little water vapour) then rises up and then flows into a tube called a **condenser**. As it travels down the condenser, it cools and condenses back into the liquid, which drips down into a collection flask. Whilst this is happening, the rest of the mixture remains behind in the boiling flask because the temperature is not high enough for it to turn into a gas.

Figure 1 shows how distillation works.

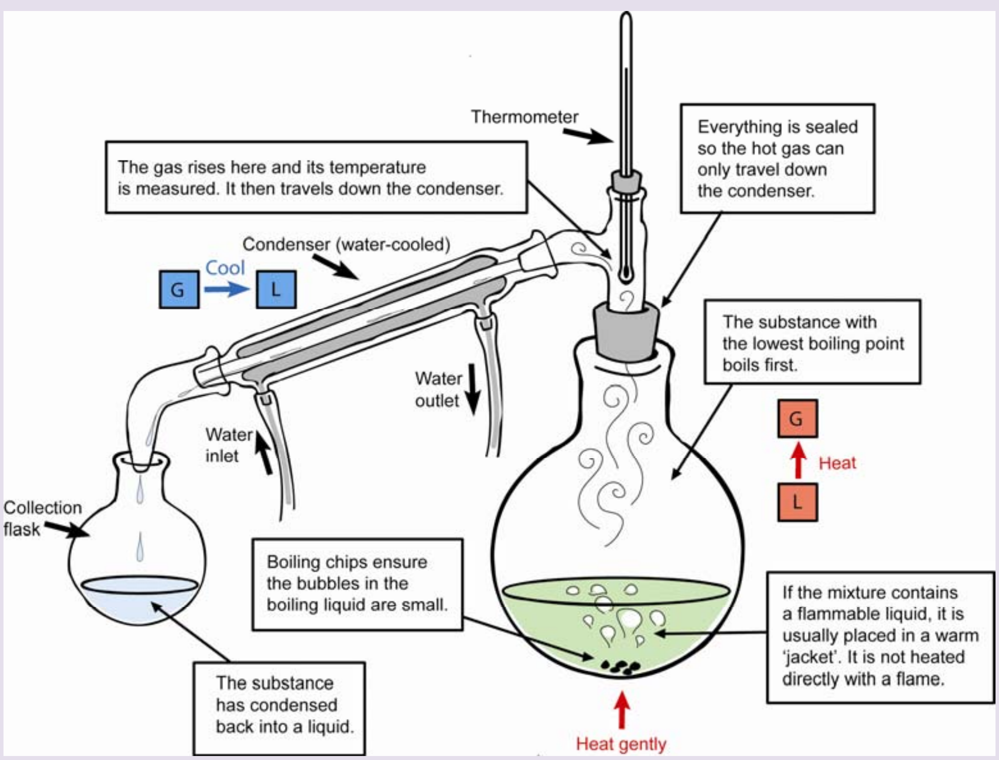


Figure 1 Performing a distillation using simple laboratory apparatus

In this activity, you will separate ethanol from a prepared mixture. This mixture is coloured.

However, instead of using the equipment shown in Figure 1, you will use the special micro-scale distillation equipment shown in Figure 3. This works on the same principles, but is designed to distil very small volumes of liquid.

Instead of a Bunsen burner or hot plate to heat the mixture, you will use a very tiny spirit burner called a microburner, shown in Figure 2. Methylated spirits is the fuel burnt in this tiny burner. Methylated spirits is often used as a fuel for larger spirit burners and small lightweight stoves used by people such as bush walkers and campers.

Figure 2 A microburner is about the size of a small birthday candle. Notice that the flame from burning methylated spirits is almost invisible. It is described as a 'clean' flame because unlike a candle flame, it does not create smoke or put black soot on objects above it.

Figure 3 This is the micro-scale distillation equipment you will use. The glass tube sloping downwards is the condenser. On this small scale you don't need the condenser to be cooled by water.

What you need

- Combo-Still set
- Sealed glass bottle containing silicone oil
- Small jar of 'boiling stones'
- Box of matches
- Paper towel
- Sealed glass bottle containing 3 mL coloured ethanol mixture
- Microburner containing methylated spirits
- Small Petri dish
- Small spatula
- Small pair tweezers

Assessing the risks

Using the micro-scale equipment greatly reduces the risks involved in distilling a mixture containing ethanol, because:

- Only very small amounts are used.
- The mixture is not directly heated by a flame but instead is heated by warm oil. (The oil used is silicone oil.)
- The equipment is held securely so it cannot fall over.
- The equipment is sealed tight so flammable vapours cannot escape.

In addition, a small spatula full of boiling stones (also called boiling chips) is added to each liquid being heated. This helps prevent it from boiling over with large bubbles.

Nevertheless, care still must be taken. Read the facts, imagine what could happen that might hurt someone or cause damage, and think of what you could do to prevent that problem. Hence complete Table 1.

Table 1 Risk Assessment

The facts	What might be the risks?	What precautions will we take?
1 All the liquids in this experiment are flammable (can catch on fire).		
2 When using the microburner, once the end of the wick has burnt, the flame from burning methylated spirits is hard to see, as shown in Figure 2.		
3 The liquids being heated will expand.		
4 Heated glass can get very hot.		
5 The ethanol mixture and the methylated spirits in the microburner both will sting eyes and any cuts and abrasions on the skin. They also can irritate even unbroken skin.		
6 All the liquids being used are poisonous.		
7 If thermometers are not very carefully handled, they can break, producing very sharp pieces of glass.		
8 Latex gloves will melt onto skin if they are heated by a flame or a very hot object.		
9 Silicone oil is a very slippery substance to handle.		

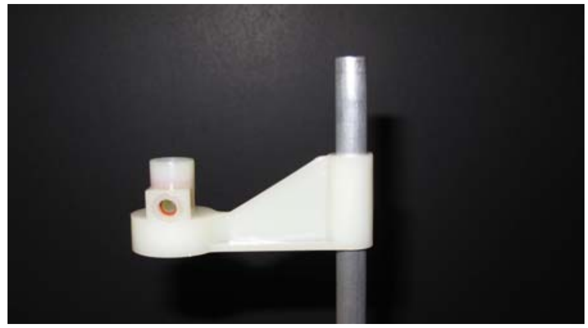
What to do and what you discover

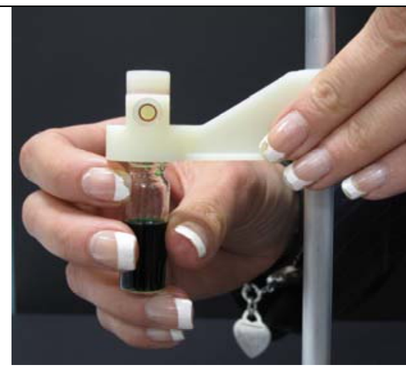
Part A Setting up the Combo-Still

Table 2 Instructions for Part A

Step	What to do	How to do it
1	Add a small spatula-full of boiling stones to the small bottle containing the coloured ethanol mixture. Then sit it in a large well of one of the comboplates until you need it, so it cannot fall over.	**WARNING!** **It is really important that the boiling stones are in each liquid!** **Do not forget this step or you may get hot oil and broken glass on you when the distillation starts!**
2	Similarly, add a small spatula-full of boiling stones to the bottle containing the silicone oil. Then place it on the Petri dish until you need it.	

<table>
<tr><td>3</td><td>Fit the Combo-Still Head onto the top of the longer metal stand, as shown in Figure 4.

Look at it from underneath to see where the bottles will screw in.</td><td>
Figure 4 The Combo-Still Head fitted onto the longer metal stand</td></tr>
<tr><td>4</td><td>Insert the stand in Well F1 in one of the comboplates. (This well is on the corner of the plate.) Make sure that it is facing in the direction shown in Figure 7.</td><td>See Figure 7.</td></tr>
<tr><td>5</td><td>Holding the small bottle containing the coloured ethanol mixture and boiling stones upright with one hand, and grasping the Combo-Still Head firmly with the other, screw the bottle into the Combo-Still Head, as shown in Figure 5.

If there are any droplets of the mixture on the outside of the bottle, wipe them off with paper towel.</td><td>
Figure 5 Screwing the small bottle into the Combo-Still Head</td></tr>
<tr><td>6</td><td>Now you will screw in the ‘outside bottle’.

Holding the larger bottle that contains the silicone oil and boiling stones upright firmly with one hand, and grasping the Combo-Still Head firmly with the other, push the bottle into the space provided for it under the Combo-Still Head, and screw it in.

The bottle of silicone oil and boiling chips should now surround the smaller bottle, as shown in Figure 6.</td><td rowspan="2">
Figure 6 The two bottles are now screwed into the Combo-Still Head. Notice the levels of the liquids. Check yours are the same.</td></tr>
<tr><td>7</td><td>Check that the silicone oil comes about halfway up the small bottle, as shown in Figure 6.

• If the amount of silicone oil in the bottle is not right, ask your teacher to assist you in adding or removing some of the oil.

• After this check, if there are any droplets of silicone oil on the outside of the bottle, wipe them off with paper towel.

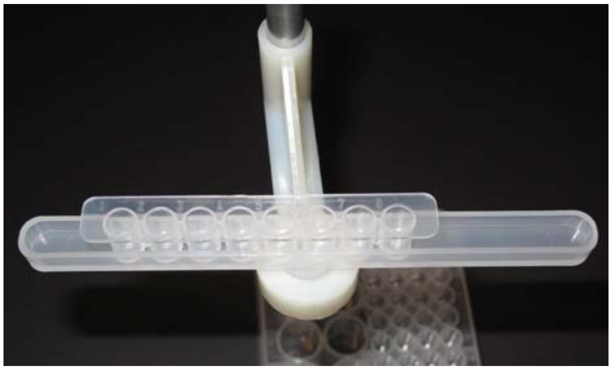
WARNING!

It is really important that both liquids are at the same levels as those shown in Figure 6. Do not start the distillation until they are!</td></tr>
</table>

8	Check that the large bottle is directly above Well F4, as shown in Figure 12 on page 64. (Well F4 will contain the microburner.) If it is not, carefully grasp the Combo-Still Head close to where it is inserted into the stand and rotate it on the stand until the bottle is over Well F4, as shown in Figure 7.	 Figure 7 The bottles are directly above Well F4 of the comboplate
9	Gently holding the thermometer near its bulb, carefully insert the bulb of the thermometer into the side hole on the Combo-Still Head, so it is firmly in place, as shown in Figure 8.	 Figure 8 The thermometer in the Combo-Still Head – viewed from above
10	Carefully remove any plastic or plug from the bent glass condenser so that the tiny glass beads remain in place. Insert the condenser into the top hole on the Combo-Still Head, so that it is firmly in place.	 Figure 9 The condenser in the Combo-Still Head

Part B   Setting up ready for the distillation

Table 3 Instructions for Part B

Step	What to do	How to do it
1	Add the other head to the other metal stand and sit it in Well F1 of the other comboplate, as shown in Figure 10. Then insert the knob on the collection tray into the hole in the ring. It should fit in tightly. The hollow part of the collection tray should now be facing upwards so it is like a narrow tray. This can be seen in Figures 10 and 11.	 Figure 10 Setting up the collection tray
2	Now sit one of the collecting vessels inside it, as shown on Figure 11. The condensed ethanol will drip into the tiny wells in this vessel.	 Figure 11 Placing the collecting vessel inside the collection tray
3	Place the microburner in Well F4 of the first comboplate. Check that it is almost full of methylated spirits and that about 1 cm of wick is hanging out. If necessary, pull more wick out with the tweezers.	*See Figure 2 for how the microburner should look.* ***DO NOT LIGHT THE MICROBURNER YET!***
4	Lower the Combo-Still Head until the bottle of silicone oil is about 2 cm above the wick, as shown in Figure 12. Move the other stand and lower the head so that the end of the condenser is just touching the first collection well, as shown In Figures 3 and 12.	*See Figures 3 and 12.*
5	**Make sure all doors and windows are shut and any air-conditioning and fans are turned off, so there will be no breezes when you start the distillation. Otherwise the tiny flame will blow out.**	

Part C The distillation

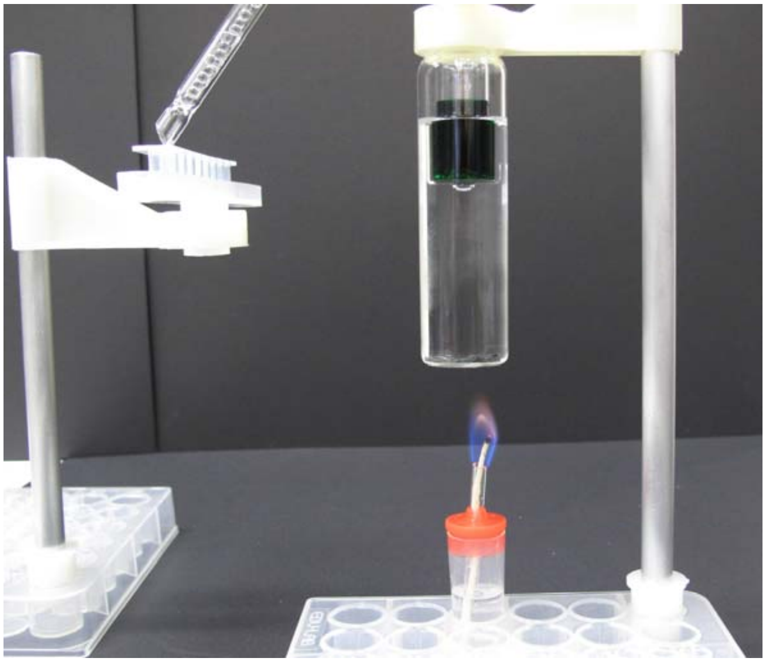


Figure 12   Starting the distillation.

Table 4 Instructions and results for Part C

Step	What to do	Observations and measurements
1	Record the temperature reading of the thermometer before you start.	The temperature is ______________
2	Light the microburner and observe the flame. Check that once the wick is burning at a steady rate, the flame does not touch the glass bottle. It should be no closer than is shown in Figure 12. If the flame is touching the bottom then raise the Combo-Still Head slightly. This means that the collection vessel also will need to be raised.	Describe the flame.
3	In a minute or two you should start to see small bubbles rising in the silicone oil, as it starts to heat up. Watch carefully what happens inside the smaller bottle.	Describe what happens to the coloured ethanol solution.
4	Within about 5 minutes you should see some liquid rising up inside the condenser. It will then start dripping down towards the collections wells. What happens to the temperature during this time? Make sure that if the collection well is almost full, you move the stand slightly so the next drips will go into the next well.	Describe what you see inside the condenser. What happens to the temperature? What is the highest temperature?
5	When you have collected a few droplets of the condensed ethanol, blow out the flame and let the Combo-Still cool.	Describe the liquid you have collected. Describe the appearance of the solution remaining in the small bottle.
6	**Pack up the equipment according to your teacher's directions. Then wash your hands with soap and water.**	

Conclusion

What is your response to the inquiry question? Were you able to separate the ethanol from the coloured mixture? ______

What evidence do you have to support your conclusion? (How could you tell it was ethanol and not water?)

____

Discussion questions

1 Explain why it's important that:

a The ethanol gas produced when the liquid boils is sealed in.

____

b The boiling stones are added to the liquids before heating.

____

c The glass bottles are not filled to the top.

____

2 Suggest why:

a The ethanol mixture is heated in a 'bath' of oil instead of heated directly by the microburner.

____

b Little glass beads are placed in the condenser.

____

3 When the ethanol mixture boils, the ethanol turns into a gas but the rest of the mixture remains behind in the small bottle. Explain why the ethanol in the mixture behaves differently to the watery solution.

____

____

4 In view of your experience, why do you think methylated spirits is chosen by hikers as a fuel for their camp stoves?

____

5 Examine a bottle of methylated spirits bought from a supermarket. Your teacher should have this on display.

a What warnings and first aid advice does it give? Are these sufficient, in your opinion? Discuss.

____

____

b Has it got a childproof safety lid? ______ Is this a good idea? Discuss.

____

Find out!

Methylated spirits is a very handy substance. Find out some of its other uses.

Some helpful information

A material safety data sheet for methylated spirits can be found at:
www.acsrotech.com.au/msds/ACS_Rotech_MSDS_Methylated_Spirits.pdf

8 FAMILIES OF CHEMICAL REACTIONS

In a **chemical reaction**, one or more new chemical substances are produced. The starting substances are called r**eactants**. The substances that are formed are called **products**.

How can you tell a chemical reaction has occurred?

Some of the signs you might observe if a chemical reaction has happened are:

- The mixture starts to bubble.
- The mixture changes colour.
- Tiny crystals (that often look like a powder) are formed that settle to the bottom of the container. (This is called a precipitate.) or a jelly-like solid is formed after mixing two transparent solutions. (This is called a gelatinous precipitate.)
- The mixture smells very different.
- A solid dissolves.
- The container starts to feels hot.
- A flame is produced.
- An explosion occurs.

Where a change is not obvious, various indicators and other tests can be performed to tell if a chemical reaction has taken place. For example, as you have discovered, an acid-base indicator can help show if an acid and a base have reacted.

What actually happens in a chemical reaction?

A chemical reaction only can occur when the particles of the reactants collide with each other. When they collide with enough energy and at the right angle, atoms are 'stripped off' and rearranged into new combinations.

For example, consider one of the chemical reactions that occur in the ozone layer (see page 11). When ozone molecules collide with each other and react, one oxygen atom is knocked off each molecule. These then join to form a 'normal' oxygen molecule. The end result is three 'normal' oxygen molecules. This is shown in Figure 1.

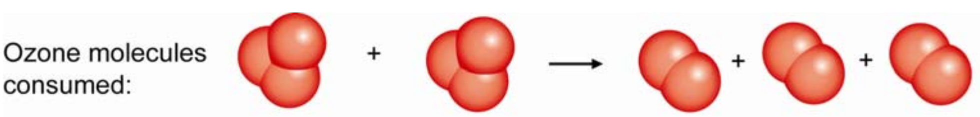
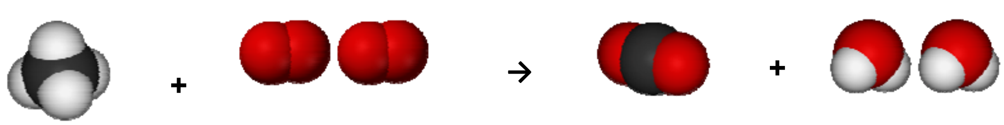


Figure 1

Notice that the total number of oxygen atoms has not changed. It's just that they now are joined in twos instead of in threes.

Consider the reaction that happens when methane burns. Methane is the main gas present in both natural gas and biogas.



methane + oxygen → carbon dioxide + water

Figure 2

Notice that the total number of carbon atoms (shown as black), the total number of hydrogen atoms (shown as white) and the total number of oxygen atoms (shown as red) has not changed. But they have definitely changed 'partners'.

The equation shown in Figure 2 is known as a **worded equation**. Chemists represent the reaction as a **balanced chemical equation**. This not only shows the chemical formulas of all the substances, but also their relative amounts and states.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Notice how this ties in with the models of the molecules in Figure 2. The numbers in front of the formulas show the relative numbers of the molecules involved. Note that (g) means gas. In this case every substance involved is in the gas state.

Classifying chemical reactions by the kind of energy transformation involved

All chemical reactions involve energy transformations. For this reason, one way in which chemical reactions are classified is by whether the reaction produces energy, or requires energy to happen.

Exothermic reactions

Exothermic reactions are reactions in which energy is produced.

Normally the energy produced is in the form of heat energy. If you mix chemicals in a conical flask and the flask starts to feel hot, you know that an exothermic reaction is taking place. In these cases the energy transformation is:

Chemical potential energy → Heat energy

Reactions in which a flame is produced are also exothermic. In these cases, the energy produced is in three forms:

Chemical potential energy → Heat energy + Light energy + Sound energy

The chemical reaction occurring inside a cell or battery that produces electrical energy is exothermic as well. Some heat energy also is produced.

Chemical potential energy → Electrical energy + Heat energy

The chemical reaction that occurs when a light stick is activated also is exothermic. In this case the form of energy produced is light energy:

Chemical potential energy → Light energy

Exothermic reactions are summarised in Figure 3.

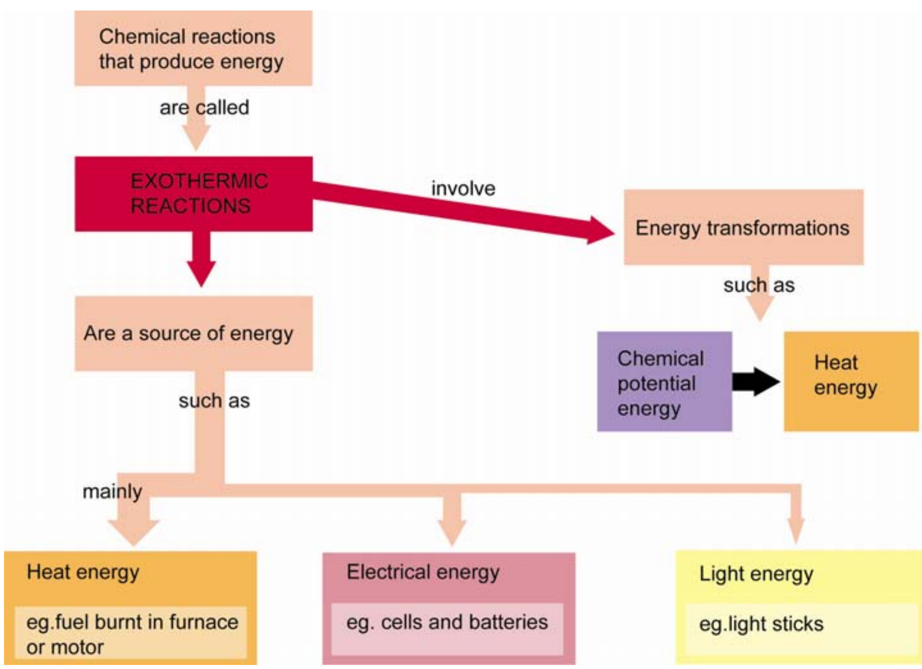


Figure 3 A flow chart to show what happens in exothermic reactions and how they can be used as an energy source

Transferring the energy produced in an exothermic reaction

The energy produced in exothermic reactions is transferred from the reaction mixture to the surroundings. For example:

• Heat energy is transferred from a reaction mixture to the container, surrounding air and any other objects in contact with it. In the case of a flame, the heat energy may be transferred to an object or substance that needs to be heated, as well as to the surrounding air, and so on.

• The electrical energy produced by chemicals in a battery is transferred to the objects in the electrical circuit.

Examples of exothermic reactions in Nature

Cellular respiration and **fermentation** are both exothermic reactions. Most living organisms obtain the energy they need to survive by one or the other of these reactions.

CELLULAR RESPIRATION: **glucose + oxygen → carbon dioxide + water + energy**

FERMENTATION: **glucose → carbon dioxide + alcohol + energy**

Bushfires are another example of exothermic reactions that occur in Nature. These involve the **combustion** of naturally occurring fuels such as trees and dried grasses and leaf litter.

COMBUSTION: **fuel + oxygen → carbon dioxide + water + energy**

Some plants depend on bushfires for their survival.

For example, the thick woody seed pods of a hakea will only open after a bushfire. This is shown in Figure 4.

This is just one example of how Australian native plants have adapted to their environment so they can survive.

The 'grass trees' that are mainly found in Western Australia similarly need the occasional bushfire to survive.

Figure 4 Hakea seed pods that have opened after a bushfire
Source:
http://sydney.edu.au/science/uniserve_science/school/sciweek/2002/regen/hakeabig.jpg
Date accessed: 15 December 2010

Endothermic reactions

Endothermic reactions are reactions in which energy is required for the reaction.

Most endothermic reactions will only occur if the reaction mixture is heated in a furnace, or over a source of heat such as a hotplate or Bunsen burner flame. In these cases the energy transformation is:

Heat energy → Chemical potential energy

Some endothermic reactions occur when electrical energy is supplied via electrodes that are inserted into the reaction mixture. (The electrodes are part of an electrical circuit.)

In these cases the energy transformation is:

Electrical energy → Chemical potential energy

Some endothermic reactions occur when light energy is supplied, such as UV light (from the Sun or a UV lamp). In these cases the energy transformation is:

Light energy → Chemical potential energy

Transferring the energy required for an endothermic reaction

The energy required for endothermic reactions is transferred to the reaction mixture from the energy source. For example:

• Heat energy is transferred to the particles of the reactants from a heat source through the container holding the reaction mixture. If the reactants are dissolved in water, then the water transfers the heat from the container to the particles of the reactants.

• Electrical energy is transferred to the particles of the reactants when they collide with the surface of the electrodes (that are part of an electrical circuit).

Endothermic reactions are summarised in Figure 5 on the next page.

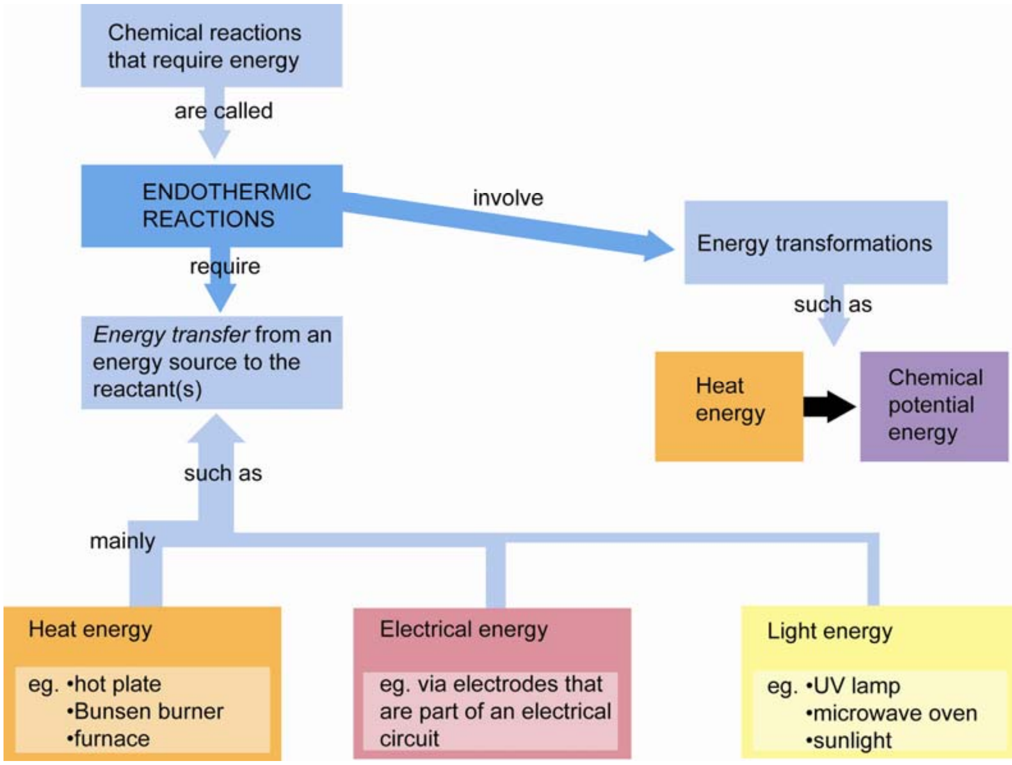


Figure 5 Endothermic reactions – the energy transformations and energy transfers involved

Examples of endothermic reactions in Nature

One example of an endothermic reaction in Nature is **photosynthesis**, which occurs in the leaves of green plants, and in other kinds of organisms such as phytoplankton.

PHOTOSYNTHESIS: **carbon dioxide + water + energy → glucose + oxygen**

The form of energy required for photosynthesis is light energy. The reaction also requires the presence of chlorophyll.

The glucose produced in this reaction is like an ‘energy store’. In the case of green plants, most of the glucose molecules produced in this reaction are joined up to produce starch and cellulose, which have giant-sized molecules. The starch is broken back down to glucose when needed, so the plant can obtain the energy it needs through cellular respiration (see the next page). The cellulose is used as a structural material.

Discussion questions

1 Outline the key difference between:

a Energy transfer and energy transformation

____

____

b Exothermic reactions and endothermic reactions

____

____

c A chemical reaction and a change of state

____

____

2 Cross-country skiers often take little pocket-sized heat packs with them. When they set the reaction going, the pack becomes very warm, and can keep their hands warm for hours.

a What kind of chemical reaction occurs in the pack – exothermic or endothermic? ______________________________

b What energy transformation occurs in the pack? ____

c What energy transfers take place that keep the skier's hands warm?

____

d One kind of heat pack mainly contains just iron filings and sawdust. The reaction is set off by peeling off a seal so this mixture is exposed to the air. The iron filings then react with the oxygen in the air. Which one of these two alternatives is most likely to be the worded equation for the reaction?

Alternative I **iron + oxygen + energy → iron oxide**

Alternative II **iron + oxygen → iron oxide + energy**

e What do you think might be the purpose of the sawdust?

____

____

Classifying chemical reactions by the kind of reactants and products involved

Chemical reactions are also divided into many different classes (or categories), depending on the nature of the reactants and products and what happened between the reactants. Table 1 shows three important classes of reactions.

Table 1 Some important classes of reactions

Class of reaction	Description	Examples
Acid-base reactions	A reaction in which an acid and a base react with one another. Note: 1 Depending on the acid and base involved, acid-base reactions are either exothermic or endothermic. 2 If they are mixed in the right proportions so that both the acid and base are completely used up, then it is also known as a **neutralisation reaction**.	• The reaction of any acid with calcium carbonate, the main substance present in sea shells, corals, marble, and so on. • In humans, when the acidic mixture of digested food (known as chyme) passes from the stomach into the duodenum, it is neutralised by basic substances.
Combustion reactions	A reaction in which a substance burns in air or pure oxygen and a flame is produced. Note: 1 All combustion reactions are exothermic. 2 All combustion reactions are also classified as **redox (oxidation-reduction) reactions**, although many other reactions, including photosynthesis and cellular respiration, are also classified as redox reactions. These names came from the fact that in the earliest known examples of these reactions, it was noticed that one reactant gained oxygen (oxidation) while the other 'lost' some or all of its oxygen content (reduction).	• The lighting of a match • Burning the gas in a gas stove, gas barbecue or Bunsen burner. • A bushfire
Fermentation reactions	A reaction in which a yeast organism processes sugar or another simple carbohydrate, forming alcohol and carbon dioxide in the process. Note: 1 All fermentation reactions are exothermic. Through this reaction, the organism gains the energy it needs to survive. 2 Fermentation reactions also are one special family of reactions within the family of redox reactions.	• The production of bioethanol from the wastes from a sugar refinery • The production of wine from grapes or other fruits • The rising of bread dough before it is baked (the high temperature kills off the yeast organisms)

What do you think?

1 All combustion and fermentation reactions are exothermic. Most acid-base reactions are exothermic, though some are endothermic. Draw a Venn diagram to represent the classes of reaction you have just learned about.

2 Complete Table 2 by classifying each chemical reaction in two different ways. The last two are partly classified for you.

Table 2

Reaction	**Exothermic or endothermic?**	**Acid-base, combustion, or fermentation?**
In peaches rotting on the ground, in the presence of yeast: **sugar → alcohol + carbon dioxide**		
In spirit stoves used for camping: **alcohol + oxygen → carbon dioxide + water**		
Dissolving a sea shell in lemon juice. It is observed that the temperature of the mixture rises slightly. **calcium carbonate + citric acid → calcium citrate + carbon dioxide + water**		
When biogas is burnt to generate electricity: **methane + oxygen → carbon dioxide + water**		
Photosynthesis, in the presence of light and chlorophyll: **carbon dioxide + water → glucose + oxygen**		None of the above. These are redox reactions.
Cellular respiration: **glucose + oxygen → carbon dioxide + water**		

3 a Aluminium metal is extracted from its ore (bauxite) by passing electricity through the molten ore via two electrodes, one of which is made of carbon. The carbon is actually consumed in the process. Which one of these two alternatives is most likely to be the worded equation for the reaction?

Alternative I **aluminium oxide + carbon → aluminium + carbon dioxide + energy**

Alternative II **aluminium oxide + carbon + energy → aluminium + carbon dioxide**

b What energy transformation occurs in this process? ______________________________

c Would this be classified as an exothermic reaction or an endothermic reaction? ______________________

d This reaction is also classified as a redox reaction. What does redox mean?

____

e This process is carried out on a large scale, and requires huge amounts of electricity, not only for extracting the metal, but also for melting the ore, which has a melting point above 1000 ºC. Running other parts of the aluminium smelter also requires a lot of electricity. Explain why the production of aluminium is regarded as a major contributor to the problem of global warming.

____

____

4 The balanced chemical equation for the fermentation of glucose, a simple sugar, is as follows:

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

a Highlight the reactant and products in the equation in two different colours. State the key below.

Key : Reactants Products

b What does (g) mean? ___________________________

c What do you think (aq) means? __________________

d Why do chemists put a 2 in front of the last two chemical formulas?

____

____

e Complete this statement: This equation tells us that for every molecule of glucose reacting, _____ molecules of ethanol and ____ molecules of the greenhouse gas carbon dioxide are produced.

Challenge questions

5 Suggest why a solid can react with a liquid or a solution or even the air, but not with another solid.

____

____

6 When you see a solid dissolve in a liquid, how might you be able to tell whether it has simply dissolved, or whether it has actually reacted with the liquid?

____

____

It's a fact!

Our atmosphere is mostly made up of nitrogen gas and oxygen gas. Normally these do not react with one another, because nitrogen is a very unreactive gas. But when lightning flashes through the air, it causes some nitrogen to react with some oxygen, forming nitric oxide, NO.

This further reacts with the oxygen in the air, forming nitrogen dioxide, NO_2. When this dissolves in and reacts with moisture in the air, it forms nitric acid, HNO_3.

The nitric acid in turn reacts with ammonia in the air, one source of which is decaying fish. Ammonia is a base. The product of this reaction is ammonium nitrate, a nitrogen-rich fertiliser that is needed by plants to produce proteins and DNA and other essential molecules. Millions of tones of ammonium nitrate rain out of the Earth's atmosphere each year!

The sequence of products and the class of each reaction is shown below. This is part of what is known as the **nitrogen cycle**, which makes nitrogen available to living things.

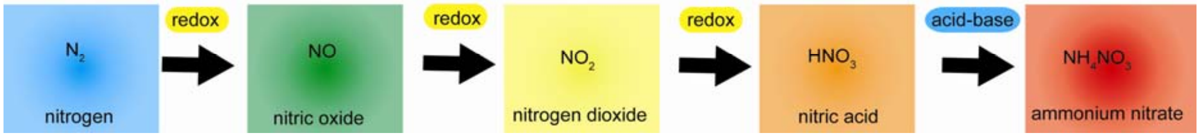


Figure 6 Part of the nitrogen cycle

The most common kind of reaction that occurs in Nature is redox reactions. (Remember that fermentation, photosynthesis, cellular respiration and combustion are all redox reactions too.) Many acid-base reactions also occur in Nature. Interestingly, in this sequence, only the first reaction is endothermic. The lightning provides the reactants with heat energy and light energy and electrical energy. All the other reactions occur spontaneously and are exothermic.

THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY

This is a coal-fired power station in Australia. Steam is rising from the cooling towers at the front. Invisible gases (including carbon dioxide) escape from the chimneys.

BIG IDEAS

Most coal-fired power stations have an energy efficiency of less than 30 per cent. What is energy efficiency?

How and why do chemists measure how much energy is wasted when fuels are burnt?

How can energy be saved?

Why are people concerned about how much we rely on coal to generate electricity?

9 THE CONSERVATION OF ENERGY: USEFUL ENERGY AND 'WASTED' ENERGY

What is 'wasted' energy?

Have you noticed how hot your mobile phone can get when you keep holding it to your ear?

Inside your mobile phone a number of energy transformations are taking place when you are using it. One is that the chemical potential energy of chemicals inside the cell is being transformed into electrical energy. However, because there is some resistance to the flow of an electrical current inside the cell, as well as in the wires, not all of the chemical potential energy is transformed into electrical energy. Some is transformed into heat energy. This is one reason why your mobile phone gets hot.

Likewise, as you no doubt have discovered, when an incandescent light globe is turned on, it gets hot. This tells us that not all of the electrical energy has been transformed into light energy – some has been transformed into heat energy. In fact, most is transformed into heat energy. This is shown in Figure 1.

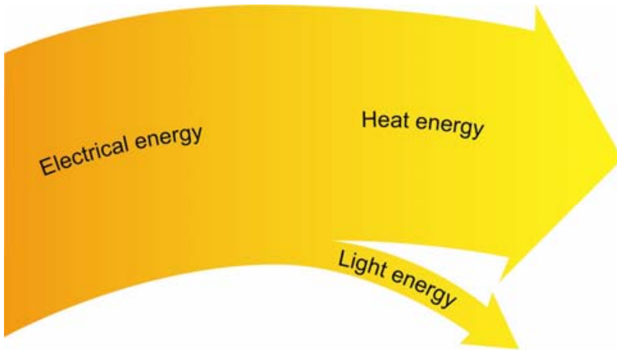
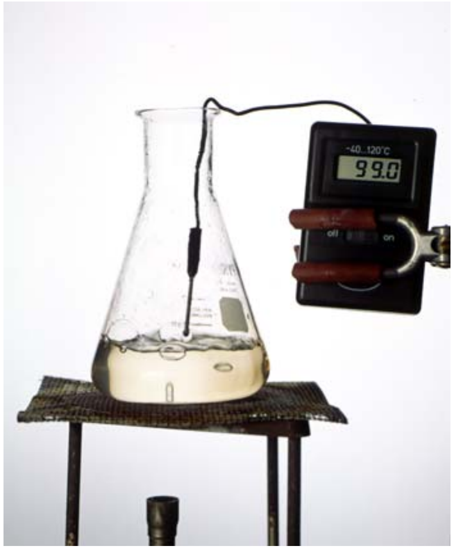


Figure 1 A Sankey diagram showing that in an incandescent light globe, most of the electrical energy has been transformed into heat energy. Only some is transformed into light energy.

When energy is transformed, the total amount of energy remains the same. This is the law of **conservation of energy**. However, whenever a form of energy is transformed, it usually is transformed into more than one other form of energy, including heat energy. Any heat energy produced in an energy transformation that cannot be used can be thought of as '**wasted' energy**.

Dissipation of energy



When you heat a solution over a Bunsen burner, ideally all of the heat energy supplied by the Bunsen burner will be used to heat the solution.

Unfortunately this does not happen. We can tell this because the tripod, gauze mat, barrel of the Bunsen burner and the glass flask all get very hot. The air near the burner warms up as well.

Why do they get hot? Some of the heat energy from the Bunsen burner is transferred to the metal in the tripod, gauze mat, and barrel and to the glass of the flask. Some is transferred to the air and a little is transferred to the temperature sensor.

The loss of useful energy due to energy transfer to other objects and materials in the environment is termed the **dissipation** of energy.

The dissipation of energy is another way energy can be wasted.

Figure 2 Heating a solution over a Bunsen burner

Measuring energy

Before you can think more about wasted energy, you need to learn about how energy is measured.

The international metric unit (SI unit) used for energy is the **joule**, symbol **J**.

The joule can be used to measure all forms of energy. Later you will learn about another energy unit, which is commonly used for electrical energy.

Measuring large amounts of energy

As with other measurement units, standard prefixes can be used for the units used to measure large amounts of energy. The most commonly used prefixes are shown in Table 1.

Table 1 Common prefixes for energy

Prefix	Symbol	Factor	Example
kilo	k	1000	One kJ is a thousand joules
mega	M	1 000 000, i.e. 10^6	One MJ is a million joules
giga	G	1 000 000 000, i.e. 10^9	One GJ is a thousand million joules
tera	T	1 000 000 000 000, i.e. 10^{12}	One TJ is a million million joules

Percentage energy efficiency

Whenever any energy resource is used, there always will be some energy wasted. To compare how effective and useful different energy resources are, scientists need to have a way in which they can measure their performance.

One way in which they can do this is to measure their percentage energy efficiency.

Percentage energy efficiency is a measure of the percentage of available energy that is useful. Ideally this should be as high as possible.

Percentage energy efficiency is measured by the formula:

Percentage energy efficiency = $\dfrac{\text{amount of useful energy obtained}}{\text{original amount of energy available}} \times \dfrac{100}{1}$

***Note:* The energy can be measured in any unit. However, the two amounts of energy must be measured in the *same* energy units.**

Examples of calculations

Example 1

Let us consider a particular incandescent light globe. Typically only 5 % of the available electrical energy is transformed into useful light energy. The remaining 95 % is 'wasted' as heat energy, as shown in Figure 3.

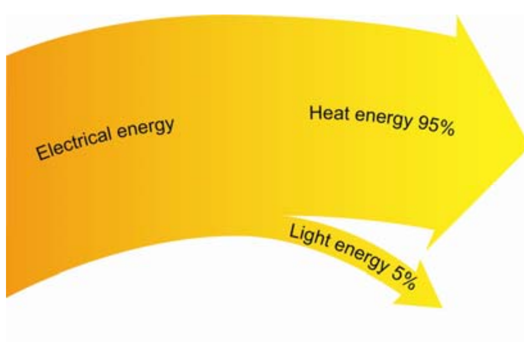


Figure 3 A Sankey diagram showing what percentage of the available electrical energy is transformed into light energy and what percentage is wasted as heat energy in a certain incandescent light globe

We say that the percentage energy efficiency of the light globe is 5 %. This means that of each 100 joules of electrical energy supplied to the light globe, only 5 joules would be transformed into useful light energy.

Example 2

Let us consider the case of boiling water in an electric kettle. In a certain experiment in which the scientist made a number of measurements, it was found that although 900 J of electrical energy was supplied to the kettle, only 765 J of energy was absorbed by the water. Calculate the percentage energy efficiency of heating the water.

Solution

Original amount energy available = 900 J

Amount of useful energy obtained = 765 J

$$\text{Percentage energy efficiency} = \frac{\text{amount of useful energy obtained}}{\text{original amount of energy available}} \times \frac{100}{1}$$

$$= \frac{765}{900} \times \frac{100}{1}$$

$$= 85\%$$

This tells us that 85% of the available heat energy was used and 15% was wasted (100 – 85 = 15).

This energy efficiency is quite high, and occurs because the kettle is made from a plastic which is a poor conductor of heat (that is, a good heat insulator), and therefore prevents most of the heat energy from dissipating.

Questions

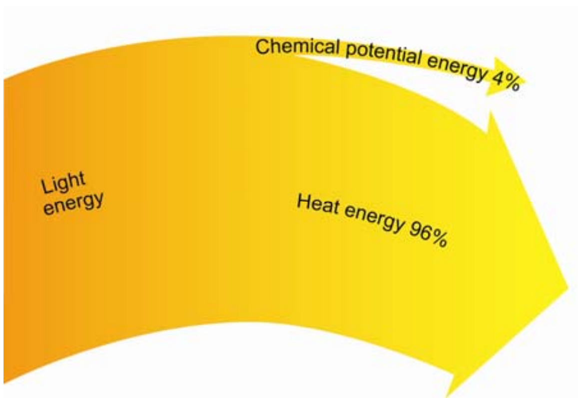


Figure 4 A Sankey diagram that represents photosynthesis in sugar cane.

1 a Write a worded equation to represent photosynthesis.

____

b What is the percentage energy efficiency of the process in the sugar cane plant? ________________

c Would you regard photosynthesis as a very efficient process, or not? Discuss.

____

d Sugar cane plants are more efficient at transforming light energy into chemical potential energy than almost all other plants. Does this result surprise you? What do you think could happen if photosynthesis was a much more efficient process for all plants?

____

____

2 The percentage energy efficiency of an LED is 50%. Draw a Sankey diagram to represent this.

3 Electrical energy is a very useful form of energy, because it can be converted into forms of energy we use daily, such as light energy, heat energy, sound energy and mechanical energy. An average Australian uses about 241 000 MJ of electrical energy per year! This is very high compared with the world average.

From this information, how much electrical energy does the average Australian use each day? Show your calculations.

4 The main energy transformations involved in producing petrol, and using it to drive a car, are shown in Figure 5.

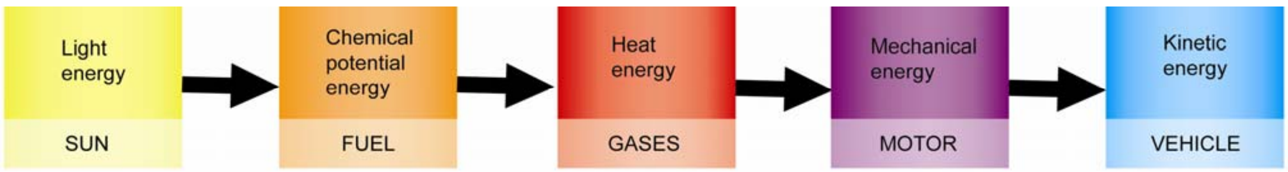


Figure 5

a The two energy transformations shown in the middle of Figure 5 occur within the car motor. The gases are produced when the fuel (petrol) burns. They push the pistons.

The percentage energy efficiency of the overall transformation of the chemical potential energy of the petrol into mechanical energy within the car motor is only around 30 %. Explain what this statement means.

____

____

b Suggest how the available chemical potential energy has been wasted within the motor.

____

____

5 In a hydroelectric power station, not all of the kinetic energy of the swiftly running water that turns the turbine is transformed into the mechanical energy of the turbine. After it has turned the turbine, the water runs down pipes to the local river system. So it still has some kinetic energy.

Suppose that during a certain period, the kinetic energy of a certain quantity of the water passing through a particular turbine is 5600 MJ and after it leaves the turbine it is 1800 MJ.

a Calculate the amount of mechanical energy received by the turbine in that period.

b Calculate the percentage energy efficiency of this process. (In reality it would be much higher than this.)

PRACTICAL ACTIVITY 5: WHICH FUEL PRODUCES THE MOST ENERGY?

Partners: ____ **Date:** ____________

Inquiry questions

1 How much heat energy do different fuels produce per gram when they burn?
2 Of the fuels tested by the class, which fuel produced the most energy?

Introduction

When fossil fuels and biofuels burn, the combustion reaction can be represented as follows:

fuel + oxygen → carbon dioxide + water + energy

The energy produced in this reaction is seen, felt and heard as a flame. One representation of the energy transformation that occurs in this reaction is shown in Figure 1.

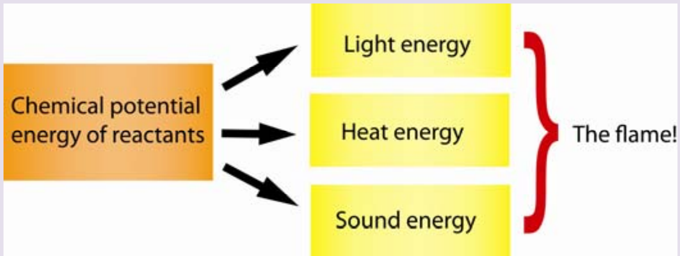


Figure 1 The energy transformations that occur when a fuel is burnt

The main form of energy produced, however, is heat energy. The Sankey diagram in Figure 2 shows this.

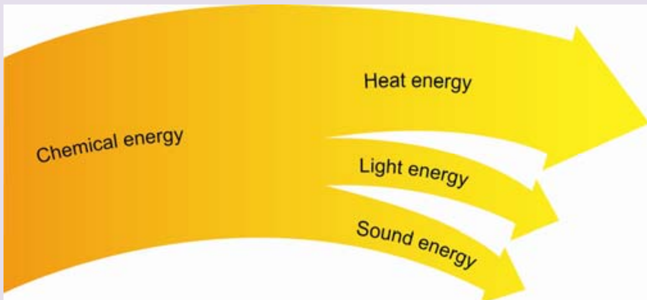


Figure 2 A Sankey diagram of the energy transformations that occur when a fuel is burnt. This shows that most of the chemical energy is transformed into heat energy.

How is energy measured?

The international unit of energy is the **joule,** symbol **J.**

It takes 4.2 joules of heat energy to increase the temperature of 1 gram of water by 1 ºC. In this activity you will use this fact to measure the amount of heat energy produced per gram of a fuel.

You will do this by using the fuel that you have been given to test, to heat a certain amount of water.

You will measure:
- The amount of water heated (200 mL, which weighs 200 g)
- The temperature of the water both before and after it is heated
- The mass of the burner plus fuel both before and after some of the fuel is burnt.

The apparatus you will use is shown in Figure 3.

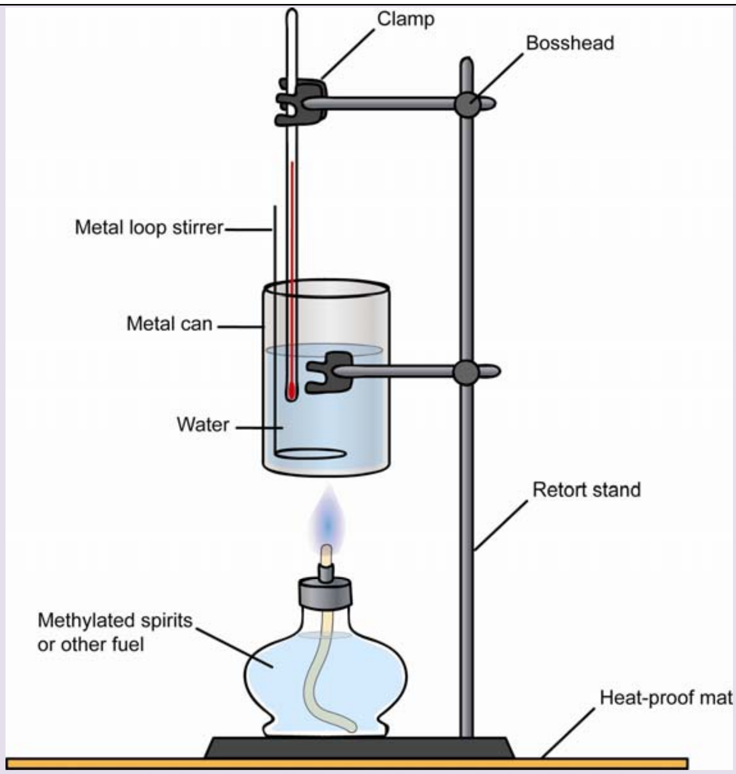


Figure 3 The apparatus used to measure the heat energy produced when a fuel burns.

How will the energy be calculated?

Since you will be heating 200 mL of water, which weighs 200 g, the formula you will use is:

$$E = \frac{4.2 \times 200 \times (T_2 - T_1)}{m}$$

where: E = heat energy produced per gram of fuel (J/g)
T_2 = final temperature of water (ºC)
T_1 = initial (starting) temperature of water (ºC)
m = mass of fuel burnt (g)

Sample calculation

A Chemistry student set up the apparatus shown in Figure 3. Using bioethanol as the fuel, she heated 200 g of water until its temperature rose by 10 ºC. Her results are shown in Table 1. What was the heat produced per gram of bioethanol?

Table 1 Sample results

Mass of water heated	Initial temperature of water	Final temperature of water	Mass of spirit burner + bioethanol before it is burnt	Mass of spirit burner + bioethanol after it is burnt	Mass of bioethanol burnt
200 g	22 ºC	32 ºC	305.42 g	305.14 g	305.42 – 305.14 = 0.28 g

Solution

$$E = \frac{4.2 \times 200 \times (T_2 - T_1)}{m}$$

where: E = heat energy produced per gram of fuel (J/g)
T_2 = 32 ºC
T_1 = 22 ºC
m = 0.28 g

$$= \frac{4.2 \times 200 \times (32 - 22)}{0.28}$$

$$= \frac{4.2 \times 200 \times 10}{0.28}$$

= 30 000 J/g (correct to 2 significant figures) **See the explanations on the next page.**

Note:

1 Notice how this solution is set out. The formula is written down, and the figures that are to be put into the formula are shown on the side. This helps avoid errors.

2 Because the temperature measurements contained only two significant figures, the answer had to be rounded off to two significant figures as well. This is because the final answer cannot be more accurate than the least accurate measurements taken.

For example, if your calculator display shows an answer like 16 380.147, it should be rounded off to 16 000 (it is closer to 16 000 than to 17 000).

What you need

- Spirit burner containing fuel allocated by your teacher
- Tin can
- 100 mL measuring cylinder
- Thermometer or temperature sensor
- Metal loop stirrer
- Retort stand with 2 bossheads and 2 clamps
- Heat-proof mat
- Box matches
- Electronic balance

Assessing the risks

Read the facts, imagine what could happen that might hurt someone or cause damage, and think of what you could do to prevent that problem. Hence complete Table 2.

Table 2 Risk Assessment

The facts	What might be the risks?	What precautions will we take?
1 The fuel is a flammable liquid.		
2 The flame will be hot, which will make the tin can hot as well.		

What to do and what you discover

Inquiry question 1: How much heat energy do different fuels produce per gram when they burn?
Inquiry question 2: Of the fuels tested by the class, which fuel produced the most energy?

Table 3 Instructions for testing the fuel allocated to the group

Step	What to do
1	Weigh the spirit burner and fuel carefully and record the mass in Table 4.
2	Set up the apparatus as shown in Figure 3. (Don't add the water yet.) Make sure that the wick height out of the burner is about 3-4 cm. Then ask your teacher to check your set-up.
3	Use the measuring cylinder to measure 200 mL of water into the tin can.
4	Measure the temperature of the cold water and record the temperature in Table 4.
5	Light the burner and stir the water slowly as it warms up.
6	When the water temperature has gone up by about 10 ºC, blow out the flame, keep stirring and measure and record the highest temperature the water reaches, and record the result in Table 4.
7	After 10 minutes, when the apparatus has cooled down, weigh the spirit burner and fuel again and record its mass in Table 4.
8	Pack up according to your teachers' directions.
9	Complete the calculations in the next section and enter your results and all the other results obtained in your class into Table 5.

Table 4 Group results
(Insert the name of the fuel you tested into the table, your measurements and the units of measurement)

Mass of water heated	Initial temperature of water	Final temperature of water	Mass of spirit burner + ________ before it is burnt	Mass of spirit burner + ________ after it is burnt	Mass of ________ burnt
200 g					

Calculations

1 Use your results to complete your calculations in the space below, as shown in the example on page 79.

2 Complete Table 5 by entering all the results obtained in the class. Where more than one result was obtained for a fuel, calculate the average and enter the answer in the last column.

Table 5 Class results

Fuel tested	Results from different groups (J/g)	Mean value (J/g)

Conclusion

1 From your results, and those of the rest of the class, what is your response to the inquiry questions?

Inquiry Question 1: How much heat energy do different fuels produce per gram when they burn?

____

Inquiry Question 2: Of the fuels tested by the class, which fuel produced the most energy? ____________________________

Discussion questions

1 a How accurate and reliable do you think your value for the heat energy of the fuel you tested was? Discuss.

____

____

b Suggest one way in which the experiment can be changed so your results would be more accurate and reliable.

____

2 Suggest reasons for the following:

a An average value of the heat energy per gram of each fuel tested by the class was calculated where more than one value was obtained.

____

____

b The water had to be stirred the whole time.

____

____

c You were asked to record the highest temperature reached by the water, not just the temperature of the water the instant the flame was blown out.

____

____

3 After watching the different fuels burning, do you think that fuels should only be chosen for the amount of heat energy per gram they can produce? If not, what other properties should be considered? Discuss.

____

____

4 Millions of people across the world still use kerosene for cooking and for lighting lamps. The heat energy kerosene produces is 43 000 J/g.

a How does the heat energy per gram of kerosene compare with the fuels you tested? Discuss.

____

____

b Kerosene is a fossil fuel. What might be two disadvantages of using kerosene as a fuel rather than using a biofuel?

____

____

Find out more!

See the feature case study ‘Lighting the World’ at www.stelr.org.au/solar-electricity/

What are some other serious problems with using kerosene in small huts for cooking and lighting?

What are two young Australian engineers doing to help solve this very big issue?

10 COAL-FIRED POWER STATIONS – THE INSIDE STORY

How much do we rely on coal as an energy resource?

The column graph in Figure 1 shows the energy resources used across the world in 2004.

It is easy to see that coal plays a very important role in supplying the world's energy needs.

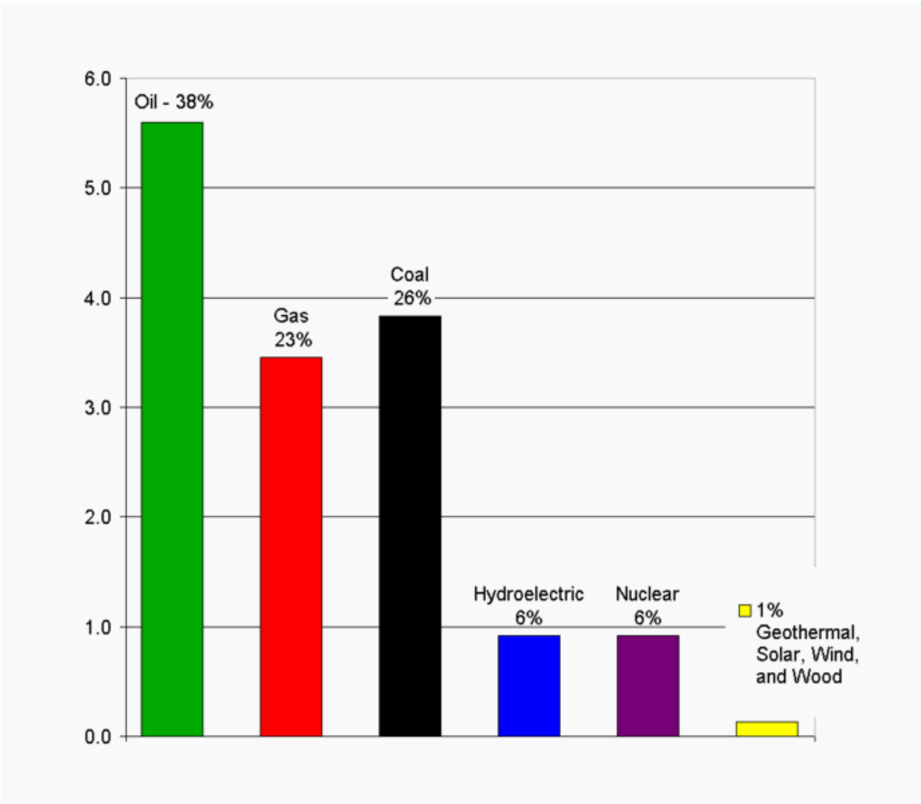


Figure 1 The percentage contribution of each energy resource to the total amount of energy used across the world in 2004.

In Australia, the percentage contribution of each energy resource is very different to the average percentage across the globe, shown in Figure 1. Table 1 shows what percentage of Australia's energy needs each major energy resource supplied in 2008.

Table 1 The contribution of different energy resources in supplying Australia's energy demands, 2008

Energy resource	Oil	Gas	Coal/peat	Hydroelectric	Nuclear	Geothermal/solar/wind	Biogas, etc.
Percentage contribution	30.3	19.8	44.5	0.8	0	0.4	4.2

Source: International Energy Agency (IEA), 2010

Discussion questions

Use Table 1 to draw a graph like the graph in Figure 1 (except you will not have figures for the vertical scale). Use a flat line to represent nuclear energy. Then use the graphs to answer the following questions.

1 What was the main energy resource across the world in 2004? ___________________________

2 What was the main energy resource in Australia in 2008? ___________________________

3 What percentage of the world's energy needs in 2004 was supplied by burning fossil fuels? ___________

4 What percentage of Australia's energy needs in 2008 was supplied by burning fossil fuels? ___________

5 What percentage of the world's energy needs in 2004 was supplied by hydroelectric power stations, solar, wind and other renewables?

____

5 What percentage of Australia's energy needs in 2008 was supplied by hydroelectric power stations, solar, wind and other renewables?

____

6 What were the biggest differences between the energy resources used in Australia and those used in the rest of the world?

____

____

7 Do you think that it is reasonably fair to compare Australia with the world when the data was for two different years? Discuss.

____

____

8 Do you think column graphs are a useful way of representing this data? Discuss.

____

____

9 What concerns do you have about the energy resources used in the world?

____

____

10 What concerns do you have about the energy resources used in Australia? What might be some solutions?

____

____

____

How does a coal-fired power station work?

Figure 2 shows the largest coal-fired power station in Victoria. It uses brown coal, which is mined nearby. (To learn more about coal, see the section on fuels, pages 44-52.)

Figure 2 Another view of the Loy Yang coal-fired power station shown on page 73. The tall chimney stacks are above the furnaces. The huge curved towers with steam pouring from them, often mistaken for the pollution from the furnaces, are the cooling towers.

PHOTO CREDIT: Loy Yang Power Station

The main stages

Figure 3 shows the main steps of the process that occurs at a coal-fired power station.

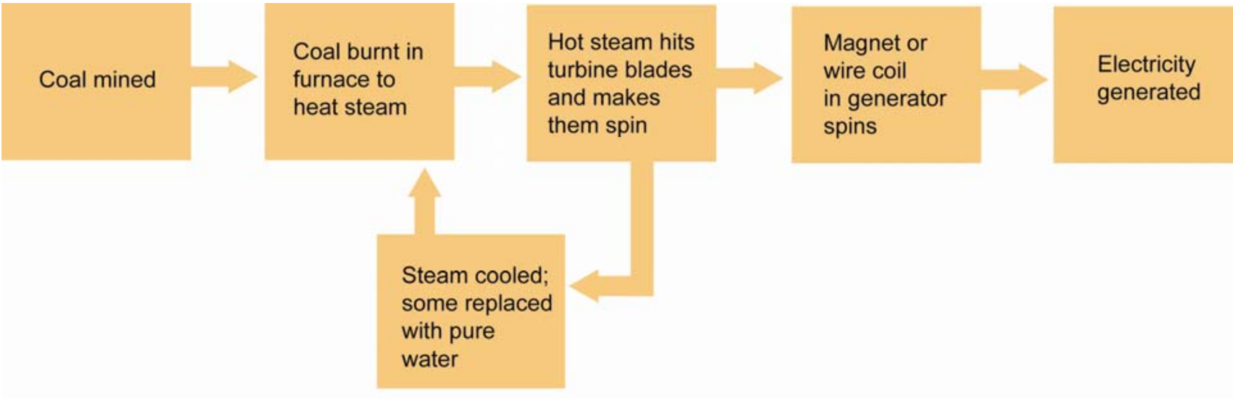


Figure 3 A flow chart for the generation of electricity at a coal-fired power station

This flow chart is explained next.

Burning the coal

Once it is mined, coal is burnt in giant furnaces. Steam is passed under pressure through pipes that are inside each of the furnaces. Steam at normal pressure has a temperature of 100 ºC. But because the steam is under high pressure, it is heated to very high temperature (several hundred degrees) inside the furnace. For this reason it is called **super-heated steam**. The higher the temperature of a gas, the faster the gas particles move. The particles of super-heated steam move very fast (35 to 100 metres per second).

Generating the electricity

The super-heated steam is then directed onto the giant turbines. Since the steam hits the blades of each turbine at enormous speed and at high pressure, it makes the turbine spin extremely fast.

This in turn causes the magnet or the wire coil inside the generator to spin, which generates an electric current.

The cooling towers

Once the superheated steam has passed over the turbine blades, it now has less energy. It is cooler and at lower pressure. It, then is passed through a huge cooling tower to be cooled further. This improves the efficiency of the re-heating process when it next passes through the hot furnace.

A little is 'bled off' and replaced with pure water to help maintain the purity of the steam, which helps protect the turbine blades, and then the steam goes around the 'circuit' again.

You can see the cooling towers in Figure 2. Read the caption carefully to identify the cooling towers and the furnace chimneys. Many people mix them up!

The energy transformations

Figure 4 shows the whole sequence of energy transformations that occur when electricity is generated from coal.

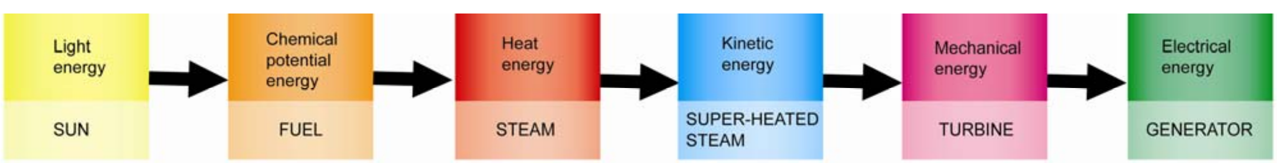


Figure 4 The main energy transformations that occur when electricity is generated at a coal-fired power station

What do you think?

1 Where does the electrical energy generated at a coal-fired power station ultimately come from? ___________________

2 Which energy transformation occurs in the furnace? Write the word ‘furnace’ above the appropriate arrow in Figure 4.

3 The overall energy efficiency of old coal fired-power stations is less than 30%. This means that less than 30% of the chemical potential energy of the coal is transformed into electrical energy. Suggest two ways in which energy would be ‘wasted’ in this kind of power station.

____

____

4 Would you expect the overall energy efficiency of a hydroelectric power station to be higher than, lower than or the same as that of a coal-fired power station? Justify your answer.

____

____

5 What do you think would be the advantages and disadvantages of locating a coal-fired power station close to the coal mine rather than near the electricity consumers?

____

____

6 The main chemical reaction occurring when coal burns is:

carbon + oxygen → carbon dioxide + energy

How might this reaction be classified? ____

The emissions of a coal-fired power station

When the coal burns in the furnaces of a coal-fired power station, a number of different gases are produced, which continually pour out of the tall chimney above each furnace. The main two gases are carbon dioxide and steam. The steam is produced as the wet coal is heated. Millions of tonnes of these two greenhouse gases are produced every day.

However, coal also contains compounds of nitrogen and sulfur, since original plants that formed the coal contained compounds of these two elements. So gases such as nitric oxide, NO, and sulfur dioxide, SO_2, are also produced. These gases react very rapidly with oxygen in the air and produce nitrogen dioxide, NO_2, which is a brown gas, and sulfur trioxide, SO_3.

As a small number of other oxides of nitrogen and sulfur also are formed, the range of oxides of nitrogen and sulfur that move out into the atmosphere are given the general formulas NO_x and SO_x and are called ‘NOX and SOX’ (see Figure 5).

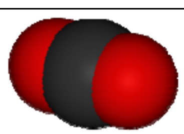
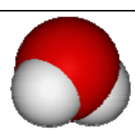
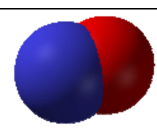
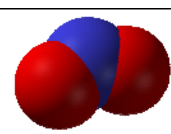
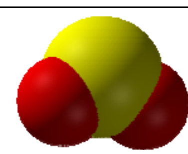
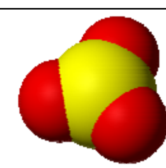
					
Carbon dioxide CO_2	Water H_2O	Nitric oxide NO	Nitrogen dioxide NO_2	Sulfur dioxide SO_2	Sulfur trioxide SO_3
The main two gases emitted		**Examples of ‘NOX’ molecules**		**Examples of ‘SOX’ molecules**	

Figure 5 Models of the molecules of some of the gases emitted by coal-fired power stations. (In molecules, atoms partially ‘merge’ into each other.)
Key: The black sphere represents a carbon atom, the blue spheres nitrogen atoms, the yellow spheres sulfur atoms, and the red spheres oxygen atoms.

What is the problem with 'NOX and SOX'?

You already know about the effect of greenhouse gases on the atmosphere. But 'NOX and SOX' also present a number of big problems.

- They are toxic and also can induce an asthma attack in asthmatics.

- They are toxic to other animals and other living organisms. For example, sulfur trioxide can enter the stomata (tiny pores) in the leaves of green plants. It then causes the leaves to turn brown and drop off, killing the plants.

- Most will dissolve in water, including in moisture in the air, and form acids, including nitric acid, HNO_3, and sulfuric acid, H_2SO_4, which are very strong and dangerous acids.

Now carbon dioxide dissolves to some extent in moisture in the air, and causes rainwater to be slightly acidic. But when NOX and SOX gases also dissolve in the moisture in the air, they form what is termed **acid rain** (and **acid snow**, depending on the conditions). The pH of these is about 3 to 4.

What can acid rain do?

Many large forests, great lakes and waterways have become 'dead zones' because of acid rain – that is, whole ecosystems have died out because their environment has become too acidic. Worse still, acid rain caused by one country can fall on another, even across the ocean!

In addition, acid rain eats into metals and slowly dissolves building materials such as marble and brickwork. A typical result is shown in Figure 6.

Figure 6 This carving has been damaged by acid rain

Are coal-fired power stations the only source of 'NOX and SOX'?

Coal-fired power stations are not the only source of 'NOX and SOX'. Vehicles and metal smelters (places where metals are extracted from their ores) are two other major sources of these gases in the atmosphere. There are natural sources as well.

What is being done about this problem?

Needless to say, when scientists investigated acid rain and identified its causes and effects, most countries started to act to reduce the problem.

In countries like Australia, the Environment Protection Agency (EPA) sets strict limits on how much of these gases can be emitted into the air by coal-fired power stations. For this reason, a very high percentage of these gases are removed from the furnace gases before they are discharged into the air. Samples of air are regularly tested to ensure these regulations are obeyed. However, the problem is that there are 'dirty' coal-stations around the globe that still emit significant amounts of NOX and SOX and therefore contribute to the production of acid rain.

What is the overall percentage energy efficiency of coal-fired power stations?

Most Australian coal-fired power stations have a percentage energy efficiency of around 30 %.

No energy transformation is 100 % efficient. For this reason, one contributing factor to the low energy efficiency of coal-fired power stations is the number of transformations that are required to produce electrical energy from the chemical potential energy of the coal.

However, a small number of power stations built recently in countries such as Germany, have a percentage energy efficiency of around 50 %. One way this much higher efficiency is achieved by using special ceramic pipes for the steam rather than metal pipes. This significantly reduces the amount of heat energy dissipated into the environment.

Discussion questions

1 a In Australia, What is a typical value for the overall energy efficiency of a coal-fired power station?   Around _____%

b Give one reason why this is relatively low.

____

2 Which two gases are the main gases emitted by a coal-fired power station? ________________________________

3 a What does the term ‘NOX and SOX’ stand for? ____

b Explain why ‘NOX and SOX’ are produced. ____

____

c Outline two problems that arise from emitting ‘NOX and SOX’ into the atmosphere.

____

____

d Are coal-fired power stations in Australia allowed to emit any amount they like of these gases? Discuss.

____

____

4 Which of the gases emitted by coal-fired power stations that are shown in Figure 5, would be classified as greenhouse gases? Justify your answer.

____

5 Suggest why coal-fired power stations like the one shown in Figure 2, page 84, have such tall chimney stacks

____

Find out more!

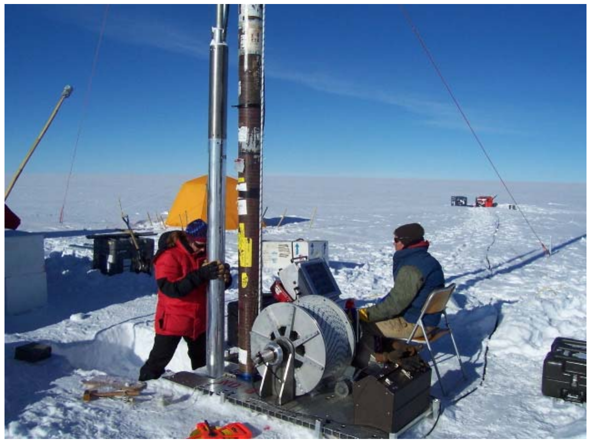
1 Find out what other substances are produced at coal-fired power stations, and what problems they cause.

2 ‘Carbon capture and storage’ is now considered to be a solution to one of the major environmental problems associated with coal-fired power stations. What does this term mean?

3 Do coal-fired power stations contribute to the electricity supply where you live? If so, where are they located? Do they have coal mines nearby? What kind of coal is this and how is it mined?

4 Read the article on geothermal energy on the STELR website. What is another way beds of coal might be used rather than being mined and burned?

HOW SCIENTISTS WORK



Not all scientists wear white coats and goggles! Scientists work in teams in many different locations. In the bottom photograph, the scientists are extracting an ice core for testing.

BIG IDEAS

How do scientists go about designing their experiments?

Which is more important for scientists – imagination or knowledge?

Should scientists be allowed to conduct any experiment they want?

Why do scientists take so many measurements and draw graphs?

11 HOW DO SCIENTISTS WORK?

When scientists observe or read about something that sparks their curiosity, and want to investigate it further, they use the process of investigation shown in Figure 1. (This process is often called the scientific method**.)**

This process is what distinguishes true scientists from **pseudo-scientists** - that is, people who pose as experts and promote their ideas but do not test their ideas and modify them in the light of the evidence those tests provide.

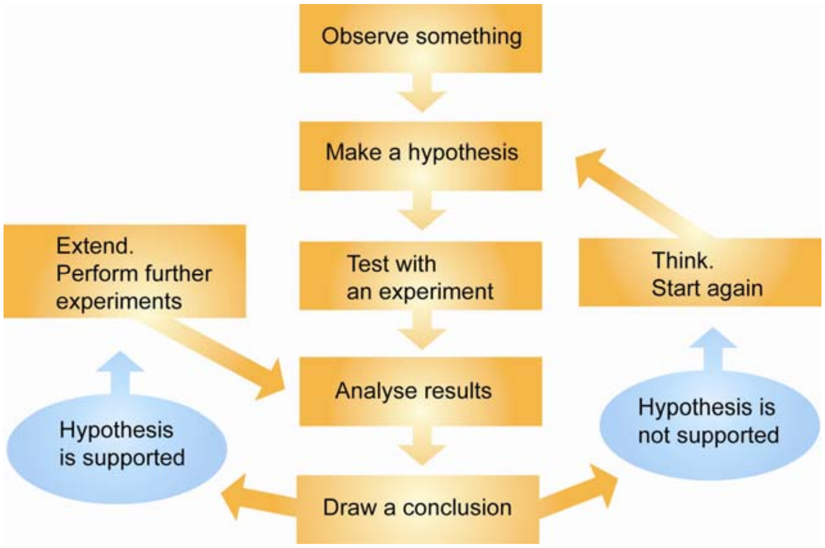


Figure 1   How scientists work

What is a hypothesis?

A **hypothesis** is a proposed explanation for some phenomenon or event that has been observed.

A **scientific hypothesis** is one that can be tested by experiment.

For example, you may have noticed that metal objects that sit in water corrode (are 'eaten away') much faster than those that are kept dry. Your hypothesis might be that water causes metal objects to corrode. Since experiments can be designed to test if the presence of water is essential for metals to corrode, this can be classified as a scientific hypothesis.

Suppose your tests show that most metals do not corrode in pure water. This surprises you, of course, but it means you will need to modify your hypothesis. You will then need to design a new investigation to test your new hypothesis.

Scientists usually have to modify their hypotheses many times, after new evidence is gathered by them or others. This is why the process that scientists use is shown in Figure 1 as a continual loop.

What is a theory?

Like a hypothesis, a **theory** is a proposed explanation for some phenomenon.

An example of a theory is the early theory that the Earth is flat. This was based on observations such as the behaviour of water in flat places and over spherical rocks. This theory led to the prediction that if you sailed far enough away from home, you would reach the edge of the Earth and fall off! Some sailors on long voyages were so petrified that they would fall off the Earth that they mutinied if the captain proposed they sailed further!

Figure 2 If the Earth was flat . . .

After the flat Earth theory was proposed, a number of philosophers and scientists argued that the theory was incorrect. (Philosopher literally means *lover of wisdom.* Philosophers are the thinkers of a society.) They proposed a new theory that the Earth is round. Eventually there was enough indisputable evidence, including scientific evidence, to support their case.

Some people think that hypothesis is just another name for a theory. This is not the case for scientific hypotheses and scientific theories, although they are alike in some ways. Where they differ is in the amount of evidence on which they are based. This is shown in Table 1.

Table 1 Scientific hypotheses and theories

Comparison	Scientific hypothesis	Scientific theory
Similarities	Proposed explanation for some phenomenon.	Proposed explanation for some phenomenon.
	Must be revised if any new data is obtained that does not support it.	Must be revised if any new data is obtained that does not support it.
Difference	Based on a limited number of observations.	Based on a huge amount of scientific evidence that has been collected over a long period of time.

Designing your own investigation

If you have a question or hypothesis you want to test, the main steps you need to use are shown next.

1 The aim of the investigation

First you must decide precisely what you are trying to discover. This is called the **aim** of the experiment.

The aim of an investigation must be very specific and reflect your hypothesis.

2 Identifying the variables

Once you have decided upon your aim, you now need to plan how you will carry out the experiment. First you must identify what variables will be operating in your experiment.

Variables are factors that may affect the outcome of an experiment. These may include factors such as temperature, the amount of light, and so on.

3 Designing a fair test

Now you must design one or more fair tests. In a **fair test,** one variable at a time is tested. This is called the **test variable**. All other variables are controlled so they do not change. That way they cannot affect the results of the test. Thus you can identify the effect of the test variable.

4 Planning to obtain reliable data

1. Wherever it is possible, scientists always take relevant measurements so that they have objective evidence. **Objective evidence** is evidence that does not depend on people's judgement. No matter which scientist takes the measurement, the result should be the same (provided the same instruments are used).
2. Scientists always have their work checked by other independent scientists before their findings are published in professional journals. If their findings are to be deemed reliable, any measurements they take must be able to be reproduced by other scientists who are performing the same experiment to check their work. So they need to choose the most accurate instrument available and to take their measurements very carefully.
3. In addition, for the variable being tested, the experiment must be designed so that there is a sufficient amount of data to be able draw a reasonable conclusion about the effect of the variable. Ideally you should be able to graph the data so that any relationships are clear. (See pages 99 to 107.) The greater the amount of data, the more reliable the conclusion will be.

So you need to decide what and how many measurements you need to take, and the most accurate way you can take them.

5 Performing a risk assessment

Once scientists have decided what tests they will do, what measurements they will take and how many, and what instruments they will use, they think very carefully about what risks will be involved and how they will minimise the risk.

To do this they gather information about the risks associated with the equipment they are using and any chemicals they will use or produce. The information sheets they obtain about chemicals are called Material Safety Data Sheets (MSDS).

They then think through each step and imagine what could go wrong, then decide how they can avoid or reduce any safety risk involved. They also ensure that they know what to do should any accident occur and that they have any safety equipment that might be required.

This is what you must do too.

6 Ethical considerations

If scientists are performing investigations that involve testing living organisms or viruses or even just DNA samples for medical, veterinary, biological or agricultural research, they must present their plans to an ethics committee for approval before they start their experiments. Likewise, if they are testing dangerous substances such as radioactive substances, they are likely to be required to obtain approval for that research.

In addition, it is always important that scientists approach their research ethically. That is, they must report their results honestly, and not change them or delete some in order to ‘prove’ their hypothesis is correct. They must be willing to acknowledge if their hypothesis was incorrect or if there are errors in their work.

Likewise, they should acknowledge any assistance they have been given from any previous research or another scientist.

You too will need to ensure you have permission to perform your experiment, and that you report your findings honestly, even if they are different to what you expected.

Performing the investigation

Once scientists know what they want to find out and how they will go about their experiment, and if they have permission where the research requires approval, they are ready to actually perform the experiment.

You will be trying out this process out yourself in the next practical activity.

Processing the results

Generally at this stage you will use your measurements to calculate quantities and /or draw graphs.

Following is some advice about performing calculations.

Advice on performing calculations

Where calculations are required, always show any formula you have used and all steps. In this way, anyone seeing your report can more easily follow the logic you have used. Any mistakes are more easily identified.

If many repeat calculations are required, it is best to show one sample calculation and devise a table to display the key ‘in-between amounts’ and final answers. This saves a lot of writing.

Note: If you need to calculate an average, the average should not have more figures than the original measurements, since it cannot be more accurate than the collected data. For example, if each measurement has 2 decimal places, then the average must be rounded off to 2 decimal places.

Drawing a conclusion

The next task you must do after processing your results is draw a conclusion. The **conclusion** is a statement of what you discovered.

Your conclusion must:

- Answer the aim.
- Be based on the results that were actually obtained. This applies even if the results were not what were expected.
- Should include a statement about whether the hypothesis has been supported, or not.

Evaluating the experiment

This is the final step of your investigation. You must judge what you did. This evaluation should include:

- An evaluation of the results. How reliable are they? (This includes identifying sources of error.)
- An evaluation of the design of the experiment. This includes identifying ways the testing could have been improved.
- An outline of further tests that could be performed to more strongly support the conclusion or to further explore the factors involved.

Discussion questions

1 What is meant by the following terms?

a Variable ____

b A fair test ____

2 Outline the difference between:

a A hypothesis and a scientific hypothesis

b A scientific hypothesis and a scientific theory.

3 Explain why scientists:

a Test a hypothesis by performing an experiment.

b Identify the variables in the investigation.

c Only test one variable at a time.

d Take a number of measurements then average the results.

e Repeat measurements using the same instrument.

f Identify sources of error in their experiment.

g Must be ethical in the way they record and report their results.

4 a Suggest why scientists spend a lot of time reading the research papers of other scientists.

b Explain why scientists must acknowledge these sources.

5 Suggest why professional journals only publish scientists work after it has been checked and found to be accurate and reliable by independent scientists.

6 Suggest why scientists must obtain the approval of an ethics committee before performing many experiments

7 In what kind of environment do you think the scientists shown in Figure 3 are working? Justify your answer.

Figure 3 Performing fair testing

12 INVESTIGATION PLANNER

What you are investigating	
What are you going to investigate?	What do you think will happen? Explain why.
What is your hypothesis?	What is the aim of your investigation?
Designing your experiment	
What variables might affect the outcome of your investigation?	Which variable(s) will you test?
How will you make your tests fair?	What observations and measurements will you need to take?
How will you ensure that your measurements are reliable?	What calculations (if any) will you need to perform?
What risks might be involved in conducting your investigation? Hence, what safety precautions do you plan to take?	What materials, including equipment will you need?

Your results

How will you record your observations and measurements? Design any suitable tables and draw them up ready in your journal. Can you use symbols and a key to avoid repeated writing of your observations? If so, have these ready under the appropriate tables.	What graphs can you draw and what spreadsheets can you design to display your results and to enable you to identify any patterns and relationships?

Conducting your investigation

Once your teacher has approved your plans and supplied the materials, conduct your investigation.

Record how you performed the investigation, in your journal. Be sure to include any modifications you made to your plans and the reasons for them.

Analysing your results: your conclusions

Examine your results. Use them to answer your aim.	From your conclusions, were your predictions and hypothesis correct? Does your hypothesis need to be modified? Discuss.

Evaluating the investigation

How reliable do you think your results were? Discuss.	How could you modify your procedure to make your results more reliable?

If you were given the opportunity, what further investigation would you carry out to build on what you learned from this investigation?

PRACTICAL ACTIVITY 6: LEMON POWER

Partners: ____ **Date:** _____________

Introduction

Did you know that a lemon can be used as a chemical cell? In fact, even potatoes, oranges and all kinds of other foods can be used to produce electricity. In this activity you will explore this for yourself.

For a lemon cell, all you need is two metal strips or rods or even nails inserted into the lemon and, of course, a complete circuit. The metal inserts are called **electrodes** because one role they play is to conduct electricity. Figure 1 shows a 'lemon cell' connected to a STELR multimeter.

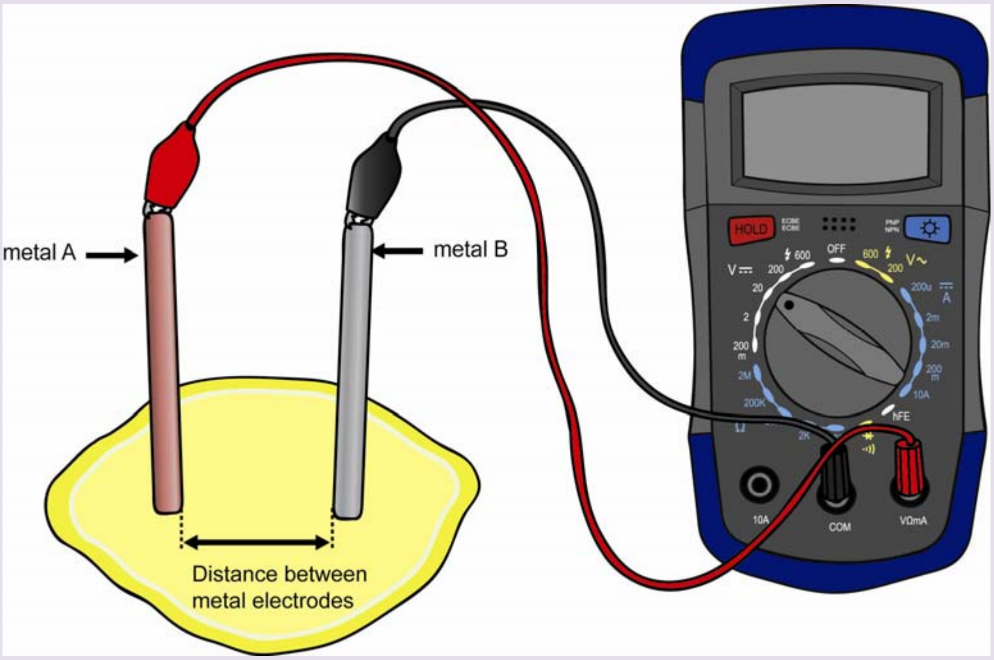


Figure 1 A 'lemon cell' – the voltage reading is not shown.

In this activity you will investigate what happens to the voltage as you reduce the distance between the electrodes.

But as you have just learned, you need to think about what other variables might be operating here. What other variables can you think of? Brainstorm your ideas and list them here!

The variables:

1 ______________________________ 2 ____________________________________

3 ______________________________ 4 ____________________________________

What do you need to do about all these other variables? ____

____

Your task

Your teachers will supply you with a lemon or potato or other food, two electrodes, wires and a multimeter, so you can create a 'lemon cell or potato cell or other food cell.

You also will have an extra copy of the investigation planner on pages 95 and 96.

Having already brainstormed all the variables that might be operating, you now need to work through the investigation planner step-by-step to investigate what relationship there is between the distance between the electrodes and the voltage.

Alternatively, you might have think of another question you want to answer!

What to do

1. **As a group, work through the process on the first page of the investigation planner and present your plans to your teacher.**

2. **When your teacher gives permission, now perform your experiment and work through and complete the second page of the investigation planner. You will need to attach your results, any graph you produce, and what you discovered.**

Discussion questions

1. Did your findings surprise you? What did you expect to happen and what did you discover?

___

___

___

2. What did some of the other groups in the class discover?

___

___

___

3. What was the general shape of the graph, and how might you explain it?

4. Comment on whether you found the investigation planner useful. What modifications would you recommend, in the light of your experience?

___

___

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13 HOW DO SCIENTISTS USE GRAPHS?

As you have learned, wherever possible, scientists measure things – and as accurately as possible. Their measurements then become part of the evidence they need in order to discover what is happening in all kinds of situations, and why.

For example, if atmospheric scientists had not been taking measurements of the temperature of the atmosphere over many years, they would not have become aware of the problem of global warming and climate change until it was too late. If they hadn't also taken measurements of the concentrations of gases in the atmosphere and in the air bubbles trapped in polar ice, they wouldn't have known why the problem was happening and hence what we could do about it.

Once they have recorded their measurements, scientists need to display and process them. One very useful way of displaying data is to use graphs.

What kind of graphs they draw depends on what kind of data they are displaying, how much data there is, and the purpose of the graph. We will consider some examples next.

Bar graphs and column graphs

Bar graphs and column graphs can be used for making general comparisons between different products.

A simple bar graph

Figure 1 is a simple kind of bar graph that compares how much carbon dioxide is produced when using ethanol from different plants as a fuel instead of petrol. (Petrol is called gasoline in the Shell report from which the graph was obtained.)

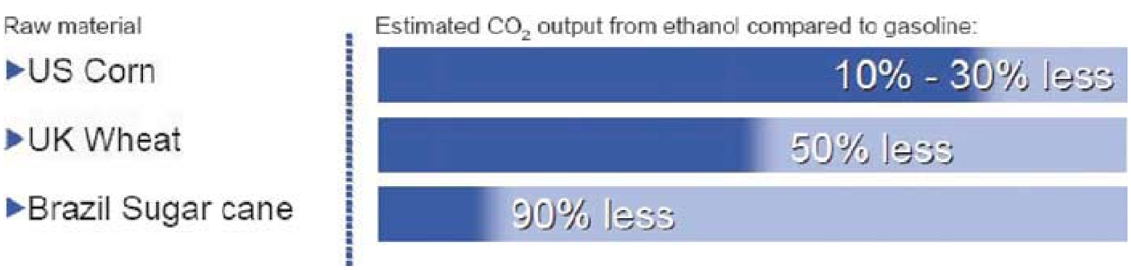


Figure 1 A comparison of bioethanol from different sources with gasoline. This takes into account the life cycle of each bioethanol, starting with growing the crop and ending with driving the car.
Source: SHELL, ENERGYNEWS – Volume 27 No. 4 December 2009, page 95.

What do you think?

Examine the bar graph in Figure 1 and answer the following questions.

1 In Brazil, bioethanol is produced and used in very large amounts. Many cars run on just bioethanol, instead of a blend of bioethanol and petrol.

a What plant is used to produce bioethanol in Brazil? ____________________________

b If a car imported to Brazil was converted to running on just bioethanol instead of on petrol, what effect would this have on the amount of carbon dioxide emitted when driving that car?

____

2 What does the graph suggest about what would be the best plant material to use to produce bioethanol in Australia? Justify your answer.

____

____

3 Since it does not show precise figures or even a scale, this cannot be regarded as a true scientific graph. However it was published in the magazine of the Australian Institute of Energy, which is read by many different people. Do you think it was easy to understand this graph? How might it be improved?

____

____

A column graph

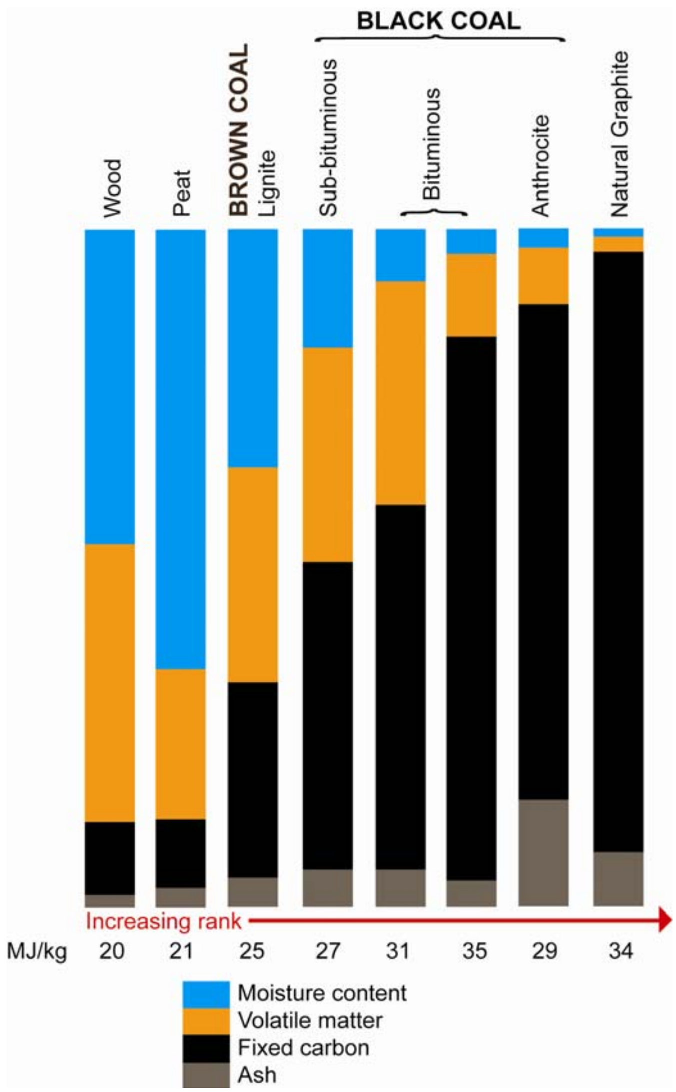


Figure 2 A comparison of the composition of different kinds of coal with wood and natural graphite. This is based on average values only. The data just below the graph states the energy obtained for each kilogram of the fuel that is burnt, in MJ/kg.
Source: The Australian Institute of Energy (*The original black and white graph has been redrawn and a key has been shown.)*

Figure 2 is a column graph that compares the composition of different types of coal with that of wood and of natural graphite. Natural graphite is an almost pure form of carbon. The 'lead' in lead pencils is really a mixture of graphite and clay. The graphite gives the 'lead' its silvery metallic sheen and its ability to stick to paper.

They are compared on:

- How much energy is obtained per kilogram when they are burnt.
- Their moisture content (what percentage of their weight is water). This is given off as steam when they are burnt.
- Their volatile matter (what percentage of their weight will turn into gases other than carbon dioxide and steam when they burn).
- Their fixed carbon content (what percentage of their weight is the carbon that burns, producing carbon dioxide).
- What percentage of their weight will become ash when they burn.

It is important to remember that:

- Wood was one of the materials that coal formed from in the first place. Many people still burn it to keep warm and cook food.
- Peat is very young coal (see page 46).
- Lignite is another name for brown coal.
- The other forms of coal shown here – sub-bituminous, bituminous and anthracite – are all classified as black coal. The lower their moisture content, the older they are.

What do you think?

Examine the graph in Figure 2 and answer the following questions.

1 Which of all the products has the highest moisture content? ____________________________

2 Which will produce the greatest amount of ash – burning 1 kg of brown coal or burning 1 kg of black coal? ______________

3 Which is the most energy-rich form of black coal (the form that gives the most energy per kilogram)? _____________

4 a How much energy would you obtain by burning 1 kg of brown coal? _____________

b How much energy would you obtain by burning 1 kg of natural graphite? _____________

5 Is it true that the higher the fixed carbon content, the greater the amount of energy obtained by burning 1 kg? Justify your answer.

____

6 Look at the arrow under the columns. What do you think the term 'rank' might mean?

____

7 Why do you think the graph label said the graph was 'based on average values only'?

____

8 Did you find the way this information was presented was clear? How could it be improved?

____

____

Line graphs –small amount of data

When an experiment has been performed in which only a few measurements were taken, any graph that is drawn will only be constructed from a few plotted points. Figure 3 shows a graph like this. It shows the concentration of ozone in the air at different times over one particular morning.

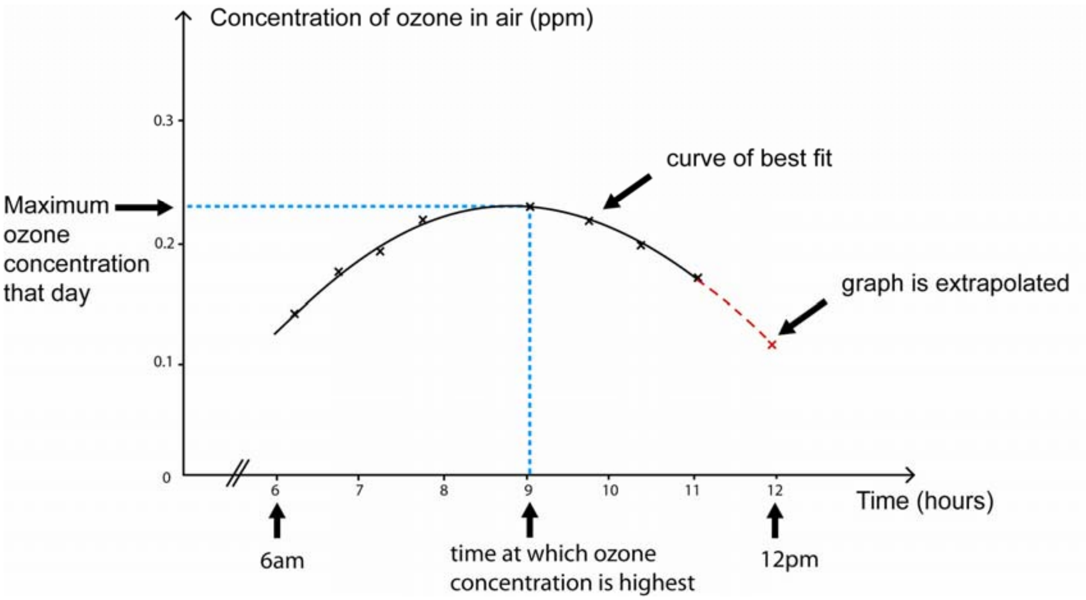


Figure 3 A graph of the concentration of ozone in the air near the ground at various times over one morning period in a particular city on a very hot summer day.

Note: The concentration unit 'ppm' is the symbol for 'parts per million'. A concentration of 1 ppm means that there is 1 litre of the gas in every million litres of air.

What the graph tells us

To obtain the data in the graph, the student measured ozone concentration at different times.

Had the points been scattered all over the graph with no particular pattern, we would have to conclude that the concentration of ozone in the air did not depend on the time of day.

But as they clearly formed a curve, we can conclude there was a relationship between the ozone concentration and the time of day.

Important features of the graph

1 Notice the two sloping parallel lines near the beginning of the horizontal axis. These mean there is a break in the scale. Often breaks are used to save space, so that more room can be used for the graph itself. As no data was collected before 6 am, it would be a waste of space to have 1 am, 2 am, etc., on the scale. The parallel lines are a conventional symbol for a break in a scale.

2 When you look at the plotted points in Figure 3, shown as crosses, it is clear they lie in a curve, not a straight line. Because they lie almost perfectly in a curve, a smooth curve is drawn that goes directly through as many of the points as possible and through the middle of the other points. This is called a **curve of best fit**. It is assumed that the points that are not exactly on the curve have 'missed' it because the measurements were slightly inaccurate.

3 Now the curve is drawn, it can be seen that the concentration of ozone rose and then fell. The maximum value of ozone concentration occurred at 9 am. Notice how inserting coloured dotted lines that go up to and across from key points on a graph helps you work out important information from the graph.

4 Suppose you want to estimate what the ozone concentration would be at 12 pm (midday). It is reasonable to assume that the graph would continue in the same way if measurements were still taken. So we continue the graph with a dotted line, to indicate this is just a prediction. We call the process of extending the graph past where the measurements were taken **extrapolating the graph**.

Dependent and independent variables

In measurement, a **variable** is a quantity that can have different values. Often scientists measure a quantity that changes over time. For example, it might be the mass or volume or concentration of a substance, or the brightness of light, or voltage delivered by a battery, or the number of bacteria present in a certain volume of nutrient solution. The scientists choose what times they will make the measurements – when they will start, when they will finish, and how often the measurements will be taken.

Because time does not depend on the quantity we are studying, and the times at which measurements are recorded can be controlled, time is called the **independent variable** in these experiments.

In this case, the ozone concentration clearly does depend on what time of day it is. So it is called the **dependent variable** in this experiment.

What do you think?

1 With a result like the graph in Figure 3, scientists would then propose an explanation for the relationship between ozone concentration and time of day.

They know that the major cause of ozone production at ground level is the action of sunlight on car emissions (the gases that come from car exhaust pipes). Other pollutants are produced as well.

Figure 4

What explanation might they suggest for the shape of the graph? Why would the ozone levels go up then down again?

---

2 Figure 5 shows a graph of the mass of carbon dioxide produced when vinegar was added to some finely crushed sea shells. (The plotted points are not shown.) The mass was measured every 10 seconds from the moment the chemicals were mixed.

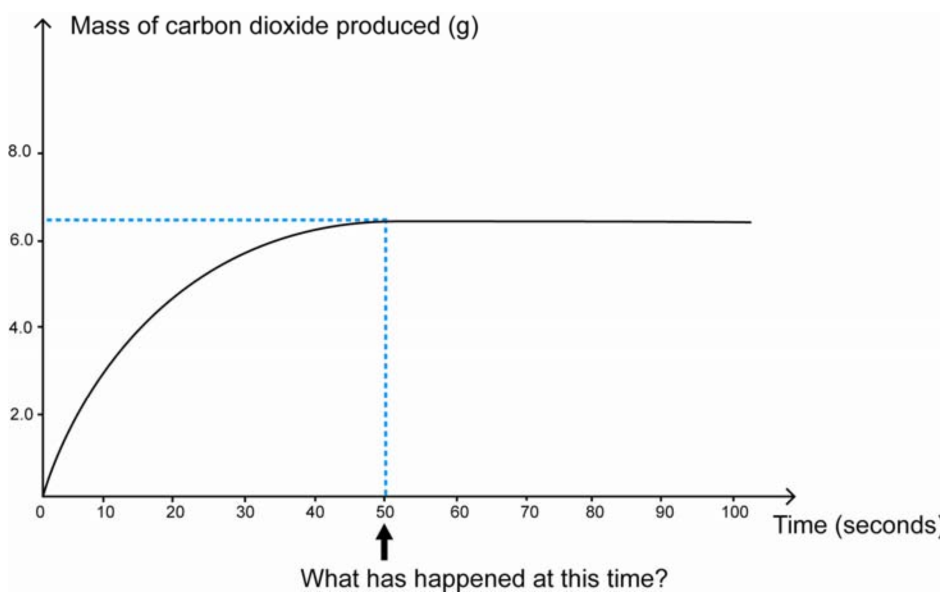


Figure 5

a What mass of carbon dioxide was produced in the first 20 seconds? _____________ Show your workings on the graph.

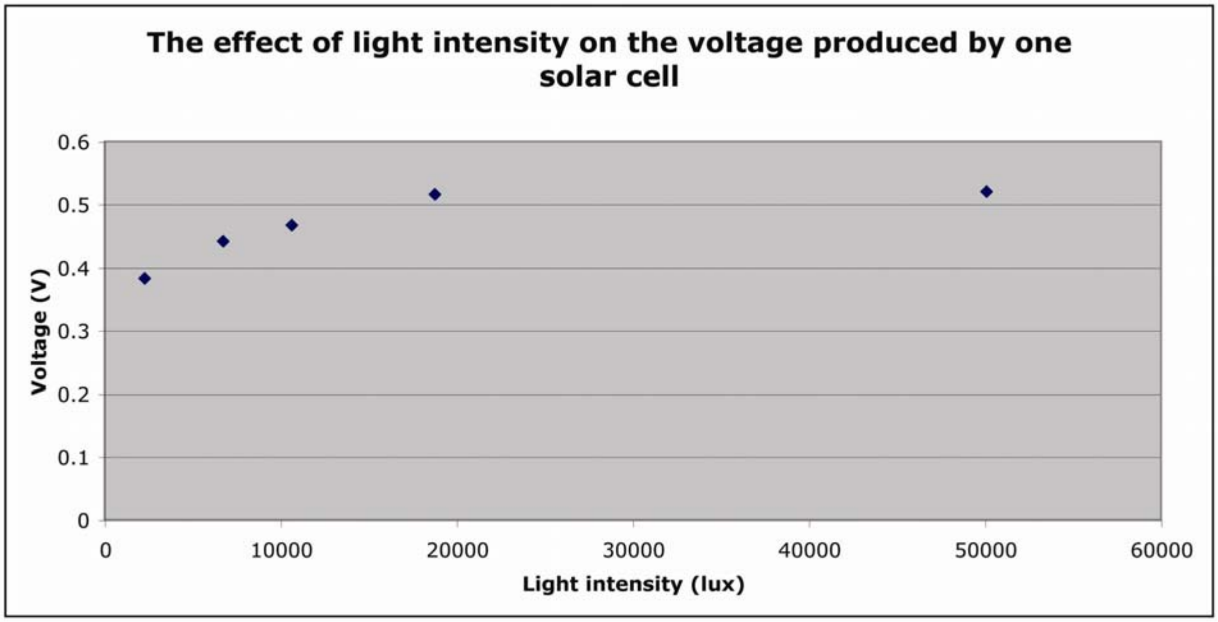
b How might you explain the fact that the graph flattens out at the 50 second mark? What has happened at this time?

____

c Which is the dependent variable in this experiment? How did you tell?

____

3 Figure 6 shows a graph produced using a graphing software program. Light was shone on a solar cell and the intensity of the light and the voltage it produced were measured. (Light intensity is a measure of how much energy the light has.)



a Sketch in a curve or line of best fit.

b Use the graph to estimate the voltage that would have been produced if the light intensity had been 60 000 lux. ______

c From the shape of the graph, what can you conclude about the amount of voltage that one solar cell can produce?

____

d What do you think are the advantages and disadvantage of this style of graph?

Advantages: ____

____

Disadvantages: ____

____

Line graphs –large amount of data

The graph in Figure 7 is another copy of the graph on page1 of this booklet. This is a typical kind of graph obtained by scientists when a large number of measurements are taken over a long time. Again this has been generated by a computer.

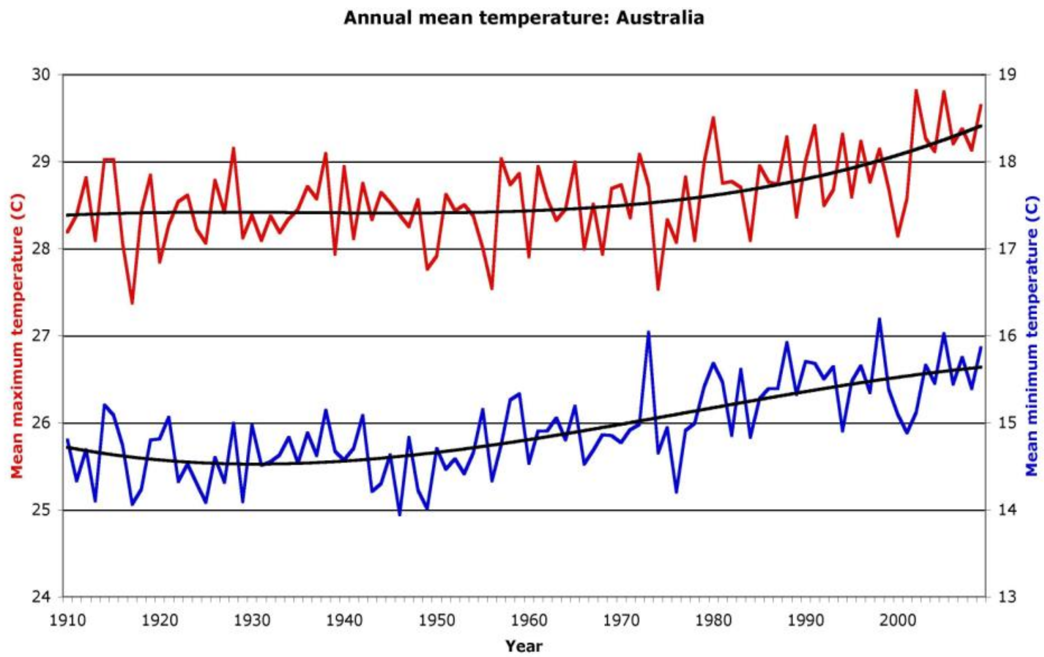


Figure 7 A graph of the annual mean minimum and maximum temperature of Australia over the last 100 years

Important features of the graph

1 Notice that two sets of data have been plotted on the same axes. The top graph (red) shows the mean maximum temperature each year. Its scale is shown on the left. The bottom graph (blue) shows the mean minimum temperature each year. Its scale is shown on the right.

2 For each graph, a value was plotted each year. The graph points were then joined with straight lines, like a dot-to-dot. The computer then determined where the curve of best fit should be placed, and inserted this in each graph. These are shown in black. Lines or curves of best fit are called **trend lines**.

What do you think?

Look at the graph in Figure 7 and answer the following questions.

1 What might be the reason for plotting the two graphs on the same axes? Is this a good idea?

____

2 What do you notice about the two vertical scales in the graph? What do you think is the reason for this?

____

____

3 What do you think is the reason the graph points were joined like a dot-to-dot? What is the advantage of doing this?

____

____

4 What do you think is the reason that trend lines were also drawn? What is the advantage of doing this?

____

____

5 a What was the mean maximum and minimum temperature in Australia in 1950?

Mean maximum: ___________________ Mean minimum ___________________

b Was it easy to work this out from the graph? Discuss.

____

____

When you draw your own graphs

Before you draw a graph, you need to design a suitable table for your results (unless one already has been provided).

Designing a table for measurements you have taken

To design a suitable results table, you need to take into account the type of, and how many, measurements you will be recording. These will determine how many columns and rows you will need and what headings you will use. Experiment with different layouts to find one that makes the recording and processing of your data as simple and efficient as possible.

Hints:

- Put units of measurements in headings where possible, so you do not have to write them many times.
- If a graph is to be drawn from the results, lay out the table as a table of values, so you can easily plot the graph.

For example, suppose you have boiled some water using a Bunsen burner, then poured it into a porcelain coffee mug. You are to investigate how the temperature of the water changes as it cools down. You plan to take a temperature reading at the start, and then another reading every minute for the next 10 minutes. A suitable table design is shown below.

Time (minutes)	0	1	2	3	4	5	6	7	8	9	10
Temperature (°C)											

Note: You can also use a spreadsheet to display the measurements you have taken.

Drawing the graph

The graph should be designed after all the measurements are taken, so you know what numbers it needs to show.

Step 1 Decide what quantity will be on each axis

Because time is the independent variable and the temperature of the water is the dependent variable, time would be shown on the horizontal axis and temperature on the vertical axis.

This way you can easily identify if there is a pattern in the way the temperature of the water changes over time.

Step 2 Choose a scale

The scales should be as spread out as much as possible so the graph is as large as possible. You are not required to use the same scale on each axis.

In this case, after completing the experiment:

- Readings were taken every minute for 10 minutes, so the time scale must go from 0 to 10.
- The highest recorded temperature was the temperature of boiling water, which is 100 ºC. So the temperature scale must go up to 100.
- The lowest recorded temperature was 60 ºC. So it is best to start the temperature scale at 60. The break in the scale should be shown.

If you are plotting the graph by hand, then a graph grid should be selected that will make the scales easy to show and the points easy to plot.

The scales should be clearly marked on the axes and the axes labelled with the quantities they represent, and their units.

Step 3 Plot the graph

The graph should now be plotted using the table of values. Figure 8 shows an example of the graph you might end up with.

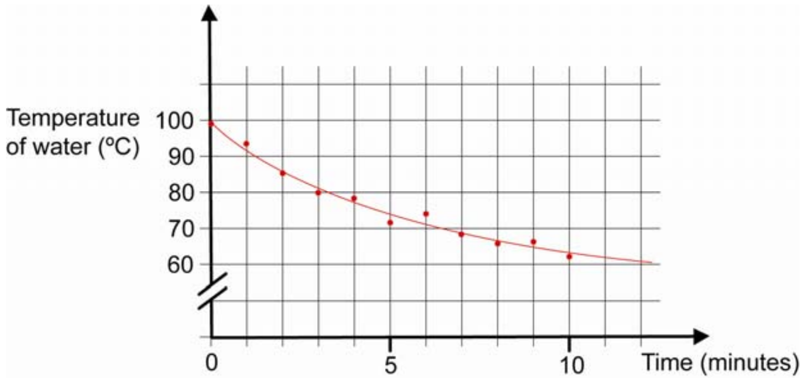


Figure 8 A graph of temperature against time for water that is cooling

Notice:

1 The graph points clearly lie in a curve. A curve of best fit was drawn.

2 The curve of best fit shows that there is a mathematical relationship between the two quantities. The graph rule can be determined using mathematical procedures, usually with the aid of a computer program.

What do you think?

Look at the graph in Figure 8 and answer the following questions.

1 What was the temperature of the water at the 3 minute mark? ________________________

2 By how much had the temperature of the water dropped at the 5 minutes mark? ________________________

3 Should the part of the curve after 10 minutes be an unbroken line like that shown on this graph or should it have been dotted in? Discuss.

____

4 On the above graph, use another colour to sketch what the graph might have looked like if a polystyrene cup had been used instead of the coffee mug. Explain your reasoning.

____

____

PRACTICAL ACTIVITY 7:
WHAT CONDITIONS MAKE A CHEMICAL CELL DELIVER THE BIGGEST VOLTAGE?

Partners: ____ **Date:** _____________

Your task

Consider the chemical cell you investigated in Practical Activity 2. This is shown again in Figure 1.

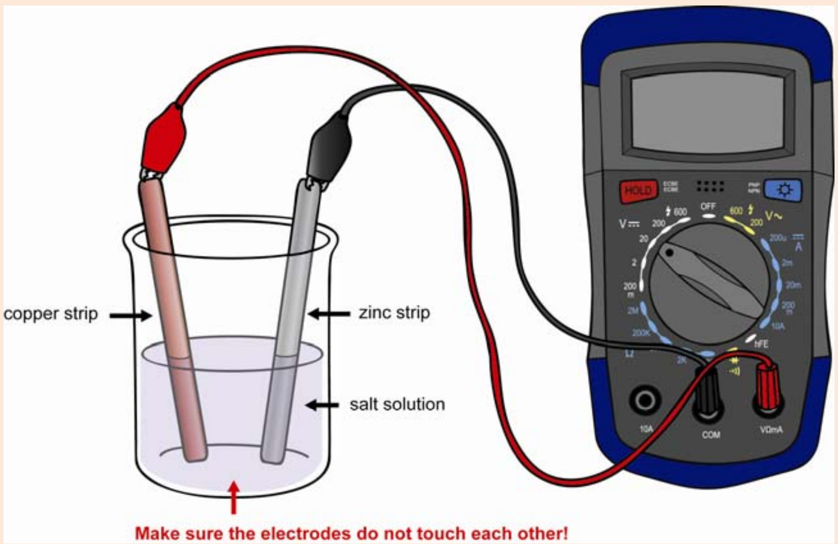


Figure 1 A chemical cell

In this activity you will investigate how you can get the biggest voltage from your chemical cell. Can your group achieve the biggest voltage in the class?

In your investigation, you may wish to modify the way the battery is set up in some way, or even what electrodes are used.

What to do

1. **As a group, work through the process on the first page of the investigation planner and present your plans to your teacher.**

2. **When your teacher gives permission, now perform the experiment and work through and complete the second page of the investigation planner. (You will need to attach your results, any graphs you draw, and so on.)**

Discussion questions

1 What conditions delivered the biggest voltage for your chemical cell? Draw a diagram.

2 What conditions delivered the biggest voltage in the class? Draw a diagram.

3 Suppose one group decided that the key to the biggest voltage was to increase the concentration of the salt in the solution (the number of grams of salt per litre of the salt solution).

To test their hypothesis, they prepared prepare several salt solutions. They recorded how much salt was dissolved in each one. Figure 2 shows some of the solutions they prepared and used.

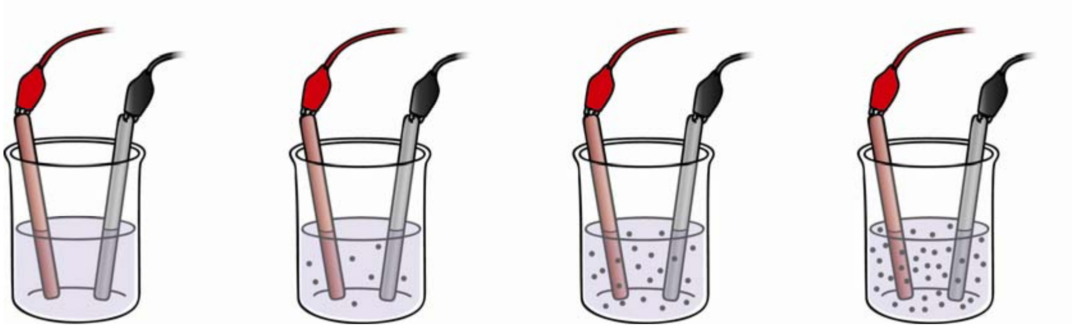


Figure 2 Testing the effect of different salt concentrations. The dots represent the dissolved salt.

a Do you think that they seemed to have set up a fair test? Discuss, stating your reasoning.

____

____

b They measured the voltage delivered for each salt concentration. Which of these quantities would be the dependent variable? Justify your answer.

____

c Suggest why the group decided to start with a salt concentration of 0 g/L.

____

d The group used the following design for their table of values.

Table 1 Testing the salt concentration

Salt concentration (g/L)	0	5	10	15	20	25
Voltage (V)						

Suggest why the group decided to increase the salt concentration by 5 g/L for each trial.

____

4 If you could repeat this investigation, what is one modification you would make to improve your accuracy? Discuss.

____

____

5 If you were given time to try extra ideas, what would be another experiment you would have performed? Discuss.

____

____

Find out more!

What kind of chemical cell is used to power the electrical systems on a Space Shuttle? What simple chemical reaction does it use?

PHOTO CREDIT: NASA