There are two broad types of organisms. Organisms made of cells that do not have a **nucleus** are called **prokaryotes**. Organisms made of cells that have a nucleus are called **eukaryotes**.

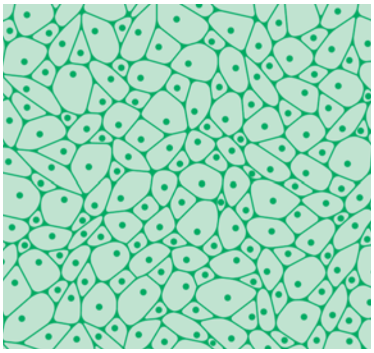


Figure 1.1: Cells

nucleus (biology)
The central part of a cell where the chromosomes are stored and from where the cell is controlled

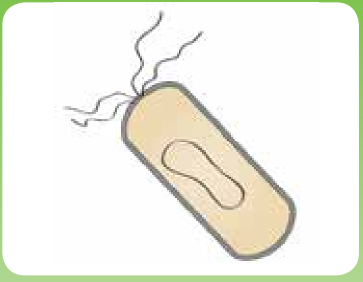
prokaryote
An organism whose cells do not have a nucleus (mostly bacteria)

eukaryote
An organism whose cells have a nucleus (plants and animals but not bacteria)

SciFACTS

An adult human is made up of around one hundred billion (that is 100 000 000 000 000) cells!

Table 1.1: Differences between prokaryotic and eukaryotic cells

Prokaryotic cells	Eukaryotic cells
No nucleus Example: bacteria  **Figure 1.2:** Cells without a nucleus	Nucleus Example: plants, animals, algae, fungi  **Figure 1.3:** Cells with a nucleus
Single loop of free-floating deoxyribonucleic acid (**DNA**)	**Chromosomes** made of DNA
Single **membrane** that surrounds the cell inside the cell wall	Membrane around the cell (inside the cell wall if present) and around **organelles**
Never form multicellular organisms	Often form multicellular organisms
Form organisms that seldom undergo sexual reproduction	Form organisms that regularly reproduce sexually
Tend to be smaller than eukaryotic cells	Tend to be larger than prokaryotic cells

DNA
Deoxyribonucleic acid, the chemical instructions for living things, made up of the four bases adenine, thymine, cytosine and guanine

chromosome
A structure found in cells that is made of DNA and carries the cell's genetic information

membrane
A thin, clear, flexible layer that protects a cell and regulates what goes in and out of it; also surrounds organelles inside eukaryotic cells

organelle
A specialised membrane-bound part inside cells

Plants and animals are both types of eukaryotic organisms, but they have some significant differences in the structure of their cells (see Figures 1.4 and 1.5).

red and blue light is captured by special structures in cells called **chloroplasts**. Green light cannot be captured by chloroplasts and is reflected; this is why most plants appear green. The light energy of the red or blue light is used to split water molecules into hydrogen and oxygen. The oxygen is a waste gas and diffuses out of the cell. The hydrogen is added to carbon dioxide to make the simple sugar glucose.

chloroplast
The specialised part of a cell in plants that captures the energy in light

The glucose molecules produced are used as fuel during respiration, or are assembled like building blocks to create tough materials (e.g. cellulose in plants) or food storage molecules (e.g. starch).

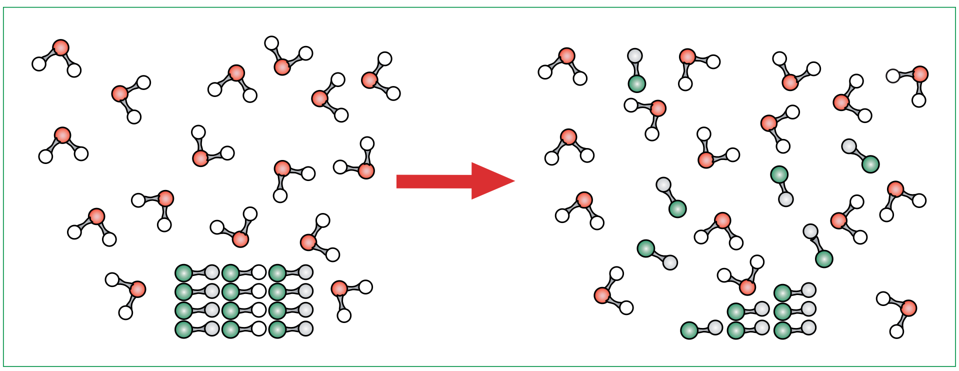


Figure 1.10: Molecules forming a solid (green and white) dissolve and diffuse

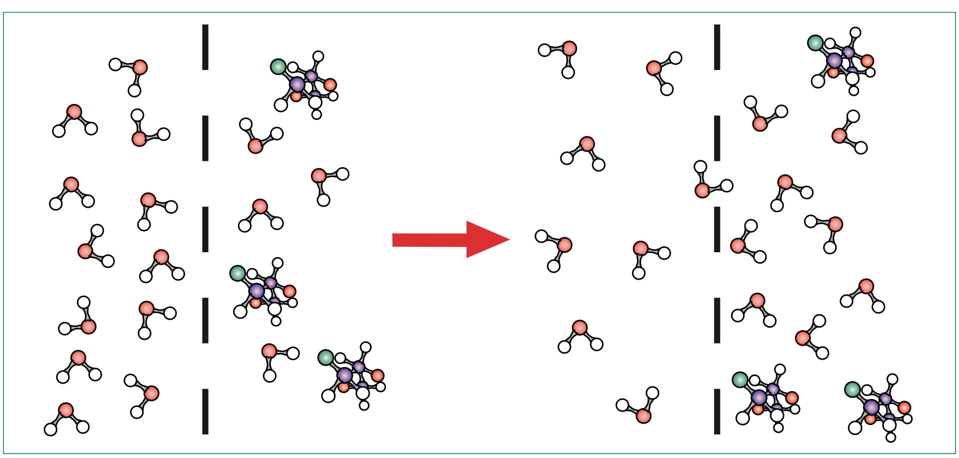


Figure 1.11: Osmosis is the movement of water (shown as the red and white molecules) through a membrane

The equation for aerobic respiration is:

$$6O_2 + C_6H_{12}O_6 \longrightarrow 6H_2O + 6CO_2 + \text{energy}$$

This means that six molecules of oxygen plus one molecule of glucose react and release energy, forming six molecules of water and six molecules of carbon dioxide as they do so.

Sometimes oxygen is in short supply. This can happen at the bottom of the ocean, in mud or warm water, when a cell is working very hard or when an organism cannot deliver oxygen to its cells quickly enough. In these situations cells will keep operating by another form of respiration called anaerobic respiration. Anaerobic respiration does not release as much energy as aerobic respiration. What is finally produced depends on the organism – in plants it is alcohol and in animals it is lactic acid. Anaerobic respiration is used to make wine and beer (when some types of yeast are placed in a sealed bottle, with sugars, they produce alcohol) and in baking (some species of yeast produce bubbles of carbon dioxide in dough, causing it to rise).

Introduced plants such as didymo, water net and oxygen weed are a problem in New Zealand because they grow so quickly they block drains, streams and the intakes of hydropower stations. However, these plants provide oxygen, food and a place to live for insects and fish. On the other hand, at night their respiration rate can be so great that oxygen levels in the water drop, sometimes to a level so low that other species die. These plants grow into large mat-like shapes, but eventually they break down and release nutrients into the water. The surge in nutrients encourages decomposers to respire and this drops the oxygen levels again, killing more species.

Figure 1.14: Didymo is a problem in New Zealand

ACTIVITY 1.3: CELL PROCESSES

1. What are three factors that affect the speed of diffusion?
2. Why is it untrue to say 'water molecules stop moving when there is osmotic equilibrium'?
3. Why will plants not grow under green light?
4. Animals and plants need both carbon dioxide and oxygen to live. Why is this?

DIGESTION

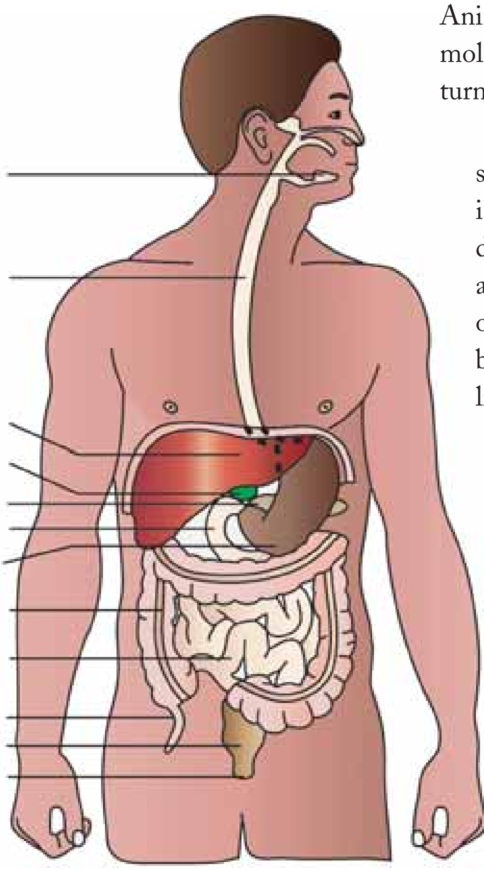


Figure 1.15: The human digestive system

Animals digest food for two reasons: to break down large molecules into small molecules so they can travel into cells, and to turn molecules that are insoluble in water into soluble molecules.

To help digestion many animals have a gut or digestive system. The gut is an extension of the skin and animals really inhabit the area between the gut and their outer skin. The gut does not digest an animal because the gut is really outside the animal. Humans are animals, too, so our digestion technically occurs outside our bodies. The lining of the gut is not digested because it is protected by a layer of slimy mucus. Parasites that live in the gut are also protected by a layer of mucus.

Mouth

Human adults have 32 teeth. Each side of the jaw has two incisors, one canine, two premolars and three molars. The upper surfaces of the premolars and molars have special interlocking ridges called cusps, which ensure food is ground up well. Human teeth are not specialised for defence or attack. They are suited to chewing a wide range of food. When chewing, the tongue rolls around the mouth and spreads food between the molars. Hunger and chewing produce saliva from the salivary glands, which surround the mouth. Every day we produce about 1 L of saliva that helps chewing and swallowing, and prevents mouth infections.

Figure 1.16: Human teeth

Oesophagus

The oesophagus connects the mouth and the stomach. Within the oesophagus is the larynx (vocal cords), and a valve called the epiglottis that allows breathing but prevents food entering the lungs when we swallow. Chewed food moves down the oesophagus and through the whole gut by **peristalsis**, muscular contractions that push the food along. In the oesophagus swallowing can start peristalsis, but in the rest of the gut it is automatically controlled. During vomiting the direction of peristalsis is reversed, often powerfully.

Cardiac sphincter

The cardiac sphincter is the first of three rings of circular muscle in the gut. It prevents acid and partly digested food in the stomach from moving back up into the oesophagus. Heartburn occurs when the cardiac sphincter relaxes and stomach acid burns the oesophagus.

peristalsis
Muscular contractions that push the food through the gut

Figure 2.7: This example of camouflage is an insect which looks like a leaf on a plant

camouflage
An adaptation that helps some organisms blend into their surroundings so that they cannot be seen

mimicry
Where one animal looks or behaves like another, usually to avoid being eaten

Adaptations may include **camouflage**, pretending to be another species (**mimicry**), and special teeth, claws, poisons, stings and spines to assist or resist predation.

These adaptations are found in both predators and prey. For example, morphine, peppermint, cloves, cinnamon and nicotine are all substances produced by plants to discourage animals from eating them. Many herbivores also make it harder for carnivores to catch them by using camouflage and speed, and by living in watchful herds.

ACTIVITY 2.1: OMNIVORE DIETS

Keep a record of what you eat over a two-day period so that you can compare how much plant versus animal material you eat. Compare your results with other students.

NEW WORDS FOR NEW IDEAS

Over the last hundred years, new ideas about organisms and how they interact with the world around them have arisen. To explain these new ideas, new words developed. At first they were only used by scientists, but as people have become increasingly aware about the environment they have become more widely used.

Species

species
Organisms that can breed and produce fertile offspring

A **species** is made up of only one type of organism. Organisms can only be the same species if they can reproduce and their offspring can go on to reproduce again. For this reason, all dogs are the same species because their puppies could grow up to be parents too. However, horses and donkeys are not the same species, because if they breed they produce mules, and mules cannot reproduce themselves. Today there are at least 2 million different species of organisms on Earth, but millions more have become extinct over the past 650 million years.

Figure 2.8: Mules are not a species because they cannot reproduce themselves (you cannot breed a mule from other mules)

Cell division

The basic unit of life on Earth is the cell, but cells wear out, so new cells must be made to replace them and to enable multicellular organisms to grow. The process of making new cells is called cell division. There are two types of cell division: mitosis and meiosis. Mitosis produces two identical cells that each have the same number of chromosomes as the original cell. Meiosis produces four different cells that each have half the number of chromosomes as the original cell.

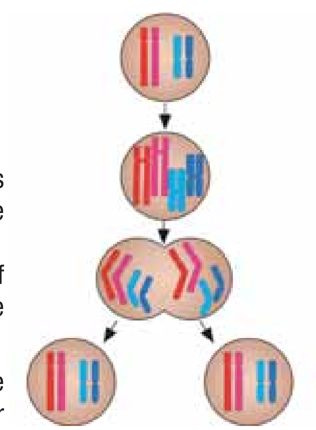


Figure 3.4: Mitosis

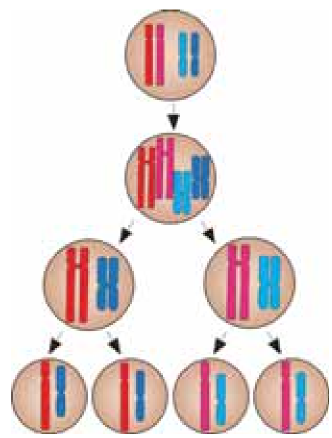


Figure 3.5: Meiosis

Table 3.1: Differences between mitosis and meiosis

Mitosis	Meiosis
The cell divides in two	The cell divides in two, and then each of those cells divides in two
Produces two new identical cells	Produces four different cells
The number of chromosomes stays the same	The number of chromosomes is halved
Occurs during growth and repair	Occurs before sexual reproduction to make eggs, sperm or pollen

Diploid and haploid

Human body cells are **diploid**, meaning they have a full set of chromosomes. In humans the diploid number is 46 chromosomes. Human sex cells (eggs and sperm) are **haploid**, as they contain half a set of chromosomes. In humans the haploid number is 23 chromosomes. We get half a set of chromosomes from each parent (when a sperm fertilises an egg).

diploid
A cell with a full set of chromosomes

haploid
A cell with half a set of chromosomes; in humans these are sex cells (eggs and sperm)

Parts of a volcano

The part of the crust that the magma begins to escape through is called a **conduit**. A conduit is like a channel. The magma (usually mixed with gas) finally blasts through the crust, forming an opening known as the **central vent**. The magma that has reached the surface is now known as lava. This lava will eventually harden. If the volcano erupts again the new lava will harden on top

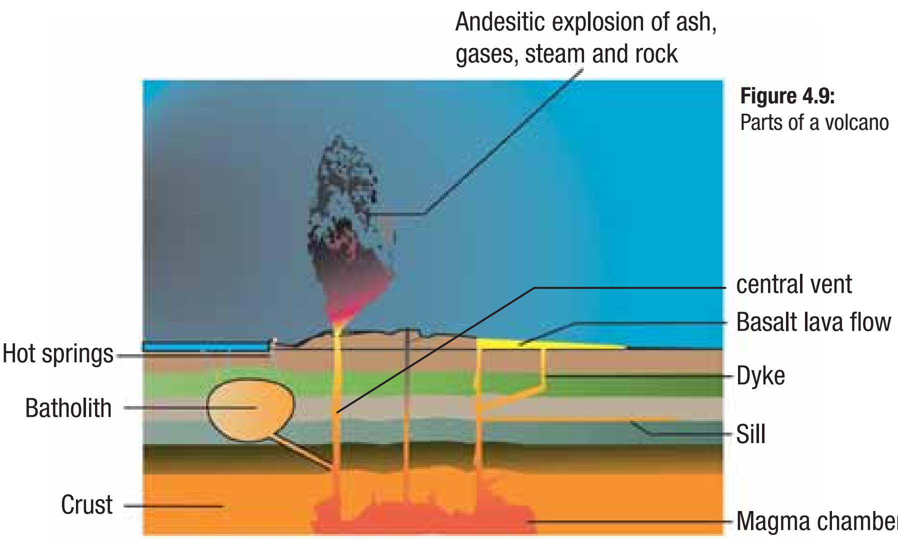


Figure 4.9: Parts of a volcano

of the previous lava. Eventually, after several eruptions, a cone-shaped volcano will form. Sometimes the magma will not be able to escape through the central vent. Instead it will find its way through the side of the volcano. These openings are called **side vents**.

As the magma moves upwards it follows the lines of weakness in the rock. When this magma cools it forms a vertical shaft of solid rock called a **dyke**. If the rising magma follows a horizontal line of weakness, such as between layers of rocks, a horizontal **sill** is formed instead.

If a large pool of magma rises from the mantle but does not reach the surface, it will distort the rocks above but not form a volcano. Large underground features like this are called **batholiths**. The massive supply of heat within them may cause **hot geothermal springs** and will metamorphose the surrounding rocks over hundreds of years.

Around the central vent a ridge usually builds up, forming a **crater**. It can fill with water, creating a lake. Over time mud, water and rocks will build up. When part of the crater wall collapses these will tumble

Figure 4.10: A crater lake

conduit
A channel in the crust through which magma flows

central vent
The main opening on top of a volcano

side vent
A smaller opening on the side of a volcano

dyke
A magma flow that moves upwards, cutting through layers of rocks

sill
A magma flow that moves sideways between layers of rocks

batholith
A large pool of magma in Earth's crust

hot geothermal spring
A spring of hot water caused by volcanic activity

crater
A circular hole, often filled with a lake, created by a volcano

WEATHER

Weather is a result of air and water moving around the troposphere driven by differences in temperature. On a small, local scale, how temperature drives air movement can be seen in coastal areas with sea breezes and land breezes.

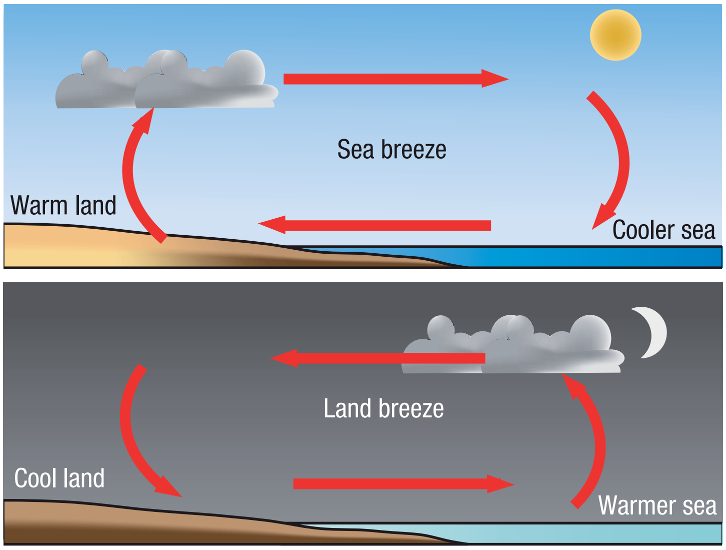


Figure 5.9: Sea and land breezes

Sea breezes

During the day the sun warms the sea and the land, but it takes more energy to warm the water. This results in the land getting warmer faster. The land warms the air above it more than the sea can warm the air above the sea. This warmer air expands and becomes less dense, causing it to rise. Air off the sea is drawn towards the land to replace the rising air. The rising air cools and is unable to hold all its water vapour, so a cloud forms. The cooled, dense air then descends over the sea.

Land breezes

At night the land cools more quickly than the sea as the warm water can release a great deal of heat energy.

Large air movements

The troposphere is the lower part of Earth's atmosphere and contains 75% of its mass and 99% of its water. At the equator the sun's infra-red radiation warms Earth's surface far more than at the poles. This warm air rises and cooler air is drawn in to replace it. On a global scale, huge convection currents are set up. Air rises at the equator and falls at each pole. There are also other bands of convection currents in-between. In addition, the rotation of Earth and its atmosphere causes the winds at the surface to curve east or west instead of blowing north or south between the lines of rising or falling air. This complex circulation is disturbed frequently by large, circular 'whirlpools' of air.

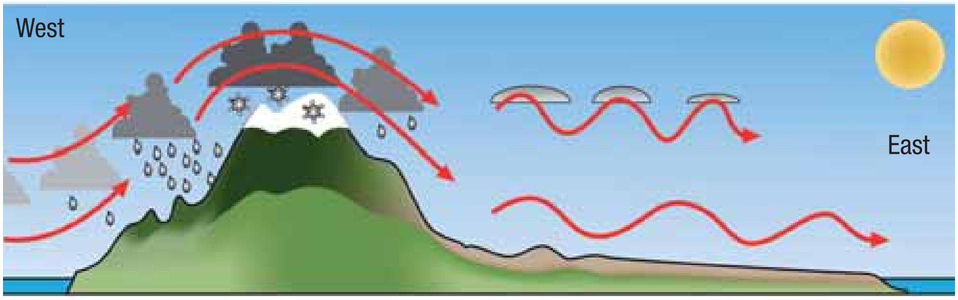


Figure 5.10: General weather pattern of New Zealand

world. Over the mountains the air descends; however, this air now has little water vapour in it so, as it descends (and is compressed), it warms rapidly as it travels east. The speed and volume of air flowing over the mountains produces bouncing waves of air (the tops of the waves are indicated by lens-shaped clouds).

THE CARBON CYCLE

All the nutrients on Earth are here in finite amounts – no extra nutrients arrive, no nutrients leave. However, all nutrients are passed or cycled along paths between soil and rocks, the atmosphere, water and organisms. The path that a nutrient can take is called a nutrient cycle. All the nutrient cycles have two kinds of tracks – fast tracks that include organisms and slower, non-living tracks that include a huge reservoir of nutrients. Nutrients that follow this pattern include carbon, hydrogen, oxygen, sulfur and nitrogen.

Figure 5.11: The carbon in coal is released into the atmosphere as carbon dioxide when the coal is burnt

Most of the carbon on Earth is found in the huge reservoir of the rocks and as carbonate minerals such as limestone. The fossil fuels coal, peat, oil and natural gas also contain carbon in a wide range of carbon compounds. The carbon in these is available to organisms only after it is released into the atmosphere either by weathering of the rocks or burning of the fossil fuels.

In the atmosphere the carbon is nearly always in the form of the odourless, colourless gas carbon dioxide. Despite huge reserves of carbon on Earth the atmosphere contains only about 0.04% carbon dioxide, although this changes naturally over time. Plants and some other photosynthetic cells combine this carbon dioxide with hydrogen from water to form glucose molecules. This is the process of **photosynthesis**, in which the carbon moves into organisms. The glucose may be **respired** immediately by cells to release energy or it may be passed through the food chain. Regardless of which occurs, the carbon dioxide is eventually released back into the atmosphere, water or soil, usually by decomposers breaking down the soft plant and animal tissues.

photosynthesis
A process where plants use carbon dioxide, water and energy from light to 'feed' themselves; this process also releases oxygen

respiration
Process where plants use oxygen to break down sugars to release energy; this process also releases carbon dioxide

SciFACTS

Theoretically, every carbon dioxide molecule from Cleopatra's body has passed through three other people since her death.

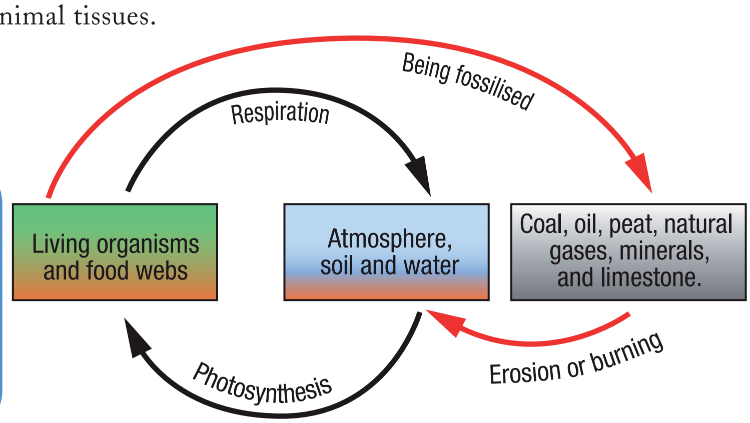


Figure 5.12: The carbon cycle

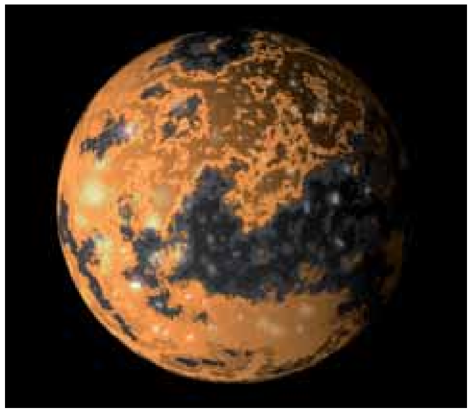


Figure 6.20: Ganymede

Figure 6.21: Callisto

ACTIVITY 6.12: OTHER MOONS

1 Which one of Jupiter's moons has volcanoes?
2 Why is Callisto not geologically active?
3 Explain why there are volcanoes and warmer than expected temperatures on some of Jupiter's moons.

ACTIVITY 6.13: EXTENSION

Answer the following questions either in a class discussion or as a research activity:

1 Ganymede is larger than Mercury. How can one be a moon and one be a planet?
2 What did the Apollo 11 mission involve?
3 What advantages could a moon base have in trying to launch a Mars mission?

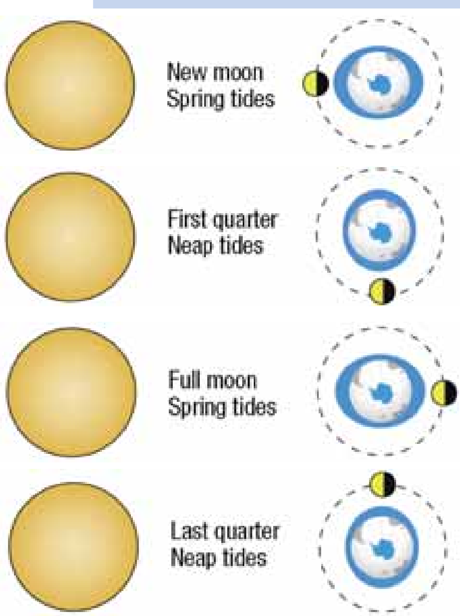


Figure 6.22: The pattern of the tides

TIDES AND ECLIPSES

Tides

Both the sun and our moon influence tides, but the moon has the greatest effect. In fact, the sun's effect is less than half of the moon's effect. On the side of Earth nearest the moon, the moon's gravity pulls Earth's water towards the moon. On the opposite side of Earth, the moon's gravity pulls the centre of Earth away from the water. This results in two high tides (and two low tides) per day as Earth rotates on its axis. In total, the time between high tides is 12.5 hours.

When Earth, our moon and the sun are in line, the sun's gravity adds to the moon's gravity to produce larger **spring tides**. These tides occur at either full moon or new moon. At the first and last quarter moon phases the sun and moon are at right angles with Earth. The sun's gravity offsets the moon's gravity and

acceleration
Change in speed over one second of time, whether speeding up or slowing down

How much a body's speed changes in a second is called **acceleration**. To work out its acceleration you need to know how much its speed changes and how long it took to make this change. You can then work out the acceleration by dividing change in speed by time taken to change.

Figure 7.10: A car's instantaneous speed will change when driven along a winding road

After distance, speed and time, acceleration is the fourth quantity used to describe motion. Acceleration (usual symbol *a*) is measured in units of speed per second. Since speed itself is 'distance per second', this means acceleration is 'distance per second per second'. When the distance is measured in metres the unit is metres per second per second, which we will write as m/s/s (there are other ways to write it but this one is simpler).

When a body's speed is increasing, its change in speed is a positive number so the acceleration will be positive. When it slows down (decelerates), its change in speed is a negative number so its acceleration will be negative.

Example 3

a A car is travelling at 20 m/s and it speeds up to 28 m/s in 4 s. What is its acceleration?

Change in the speed of the car = (speed at end) – (speed at beginning)
= (28 – 20) m/s
= 8 m/s

Time taken to change the speed = 4 s

Acceleration $= \dfrac{\text{change in speed}}{\text{time taken}}$

$= \dfrac{(8 \text{ m/s})}{(4 \text{ s})}$ m/s/s

= 2 m/s/s

The car accelerates at 2 m/s/s.

b The car slows down from 28 m/s to 8 m/s in 5 s. What is its acceleration now?

Change in the speed of the car = (speed at end) – (speed at beginning)
= (8 – 28) m/s
= -20 m/s (negative because it is slowing)

Time taken to change the speed = 5 s

Acceleration $= \dfrac{\text{change in speed}}{\text{time taken}}$

$= \dfrac{(-20 \text{ m/s})}{(5 \text{ s})}$ m/s/s

= -4 m/s/s (negative acceleration, i.e. deceleration).

The car decelerates at 4 m/s/s.

The Law of Conservation of Energy:

1. **Energy cannot be created out of nothing.**
2. **Energy can change form, but the total amount of energy in a closed system is always the same.**
3. **Energy cannot be destroyed.**

Machines transform energy from an available energy resource (e.g. oil) to useful energy that can do the work we want (e.g. electricity). By the Law of Conservation of Energy, the energy input is equal to the energy output. Unfortunately, in a machine energy transformations always result in some of the wrong form of energy being produced: waste energy rather than useful energy.

For example, we put electrical energy into a light bulb, and the useful energy we want to get out is the radiant energy as light. But heat energy and infra-red radiant energy are also produced. These are waste energy.

Energy input of a light bulb:	→	Energy outputs of a light bulb:	
Electrical energy		Useful energy:	Waste energy:
		• Light energy	• Heat energy
			• Infra-red

We want the maximum amount of useful energy from the light bulb. A device that produces a lot of useful energy and little waste energy is said to be efficient. It is convenient to measure and record how energy efficient a device is using the **energy efficiency** formula:

energy efficiency Useful energy output of a device as a percentage of its energy input

$$\text{Energy efficiency } \% = \frac{\text{useful energy output (J/s)} \times 100}{\text{energy input}} \%$$

For the energy efficiency of a device that is running continuously, we measure the energy input and useful energy output **per second** (unit J/s).

An energy efficiency of 100% means that all the energy output is useful (in practice no devices achieve this, there is always some waste energy output).

Example 12

A standard 100 watt light bulb has a metal filament that glows when heated by electricity. It uses 100 J of electrical energy per second. About 90 J/s is waste heat energy. Its energy efficiency is:

$$\text{Energy efficiency of a standard light bulb} = \frac{10 \text{ J/s} \times 100 = \%}{100 \text{ J/s}}$$

$$= 10 \%$$

An energy-saving light bulb uses gas in a tube rather than a metal filament. A 20 watt light bulb of this type produces the same amount of light energy as a standard light bulb. Its energy efficiency is:

$$\text{Energy efficiency of an energy-saving light bulb} = \frac{10 \text{ J/s} \times 100 = \%}{20 \text{ J/s}}$$

$$= 50 \%$$

Electrical charges come from inside **atoms**. Everything in the world is made up of atoms. Atoms are made up of positive particles called **protons**, negative particles called **electrons** and neutral particles called **neutrons**.

atom
The smallest component of an element that contains all the properties or characteristics of that element

proton
A particle found in the nucleus of atoms; has mass and positive electrical charge

electron
A particle found in atoms; has mass and negative electrical charge

neutron
A particle found in the nucleus of atoms; has mass but no electrical charge

Figure 8.1: Static hair is caused by electrical charge

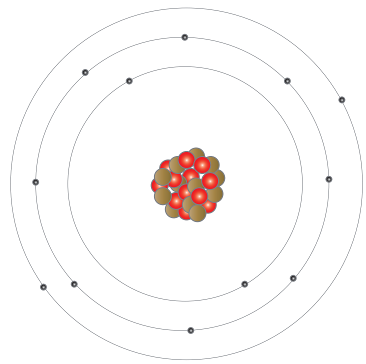


Figure 8.2: A diagram of an atom

Neutrons and protons are stuck together in the nucleus of an atom, and electrons move around the nucleus. Electrons have the opposite charge to protons. Atoms have equal numbers of protons and electrons, so their electrical charge cancels out. An atom that has an equal number of protons and electrons is neutral (it has no electrical charge). For example, carbon atoms always have 6 protons. If a carbon atom has 6 electrons it has no charge and is neutral.

Atoms can sometimes gain electrons from other atoms that pass by. Then the atoms have more electrons than protons and they get an overall **negative charge**. For example, oxygen atoms always have 8 protons. If an oxygen atom has 10 electrons it has more electrons than protons so it is negatively charged.

Atoms can also lose electrons. Then the atoms have more protons than electrons and they get an overall **positive charge**. For example, sodium atoms always have 11 protons. If a sodium atom has 10 electrons it has more protons than electrons so it is positively charged.

As neutrons have no charge (they are neutral) they have no effect on the overall charge of the atoms.

negative charge
The type of electrical charge electrons have; objects with more electrons than protons have a negative charge

positive charge
The type of electrical charge protons have; objects with more protons than electrons have a positive charge

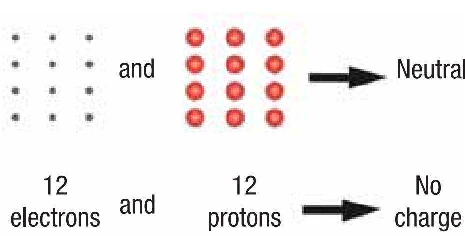


Figure 8.3: Atoms with an equal number of protons and electrons are neutral

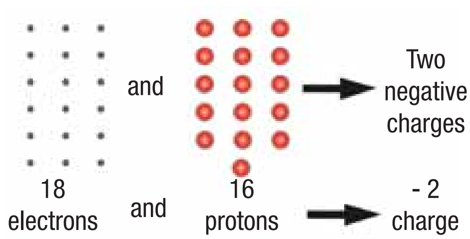


Figure 8.4: Atoms with more electrons than protons have a negative charge

Paint guns

Paint guns used to paint cars have a special device that charges the droplets of paint so that they all have the same charge. This makes the spray of paint more even than the spray of paint from a paint spray can.

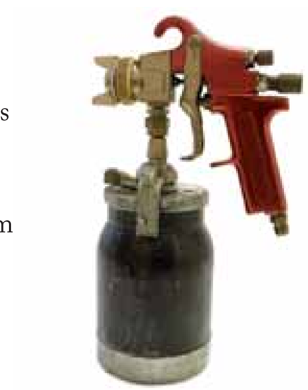


Figure 8.12: Paint guns spray paint more evenly than paint spray cans

ACTIVITY 8.6: ELECTRICAL FORCES

1 Describe the force between the paint droplets that are sprayed from a paint gun.
2 Why does making paint droplets charged help make paint spray evenly?

ELECTRICAL CIRCUITS

An electrical **circuit** uses the flow of electrical charges to make an electrical appliance work. A functioning electrical circuit must include:

1. A **power source**. Examples of power sources are batteries, power packs and the household power source that comes from a power station (mains power).
2. An **energy converter**. Examples are light bulbs, heaters, fans, televisions and ovens.
3. A **complete circuit**. A circuit is a path of wires from the negative terminal of the power source, through the energy converter, to the positive terminal of the power source.

circuit
A complete path of electrical conductors where electricity flows

Figures 8.13, 8.14 and 8.15: Power sources – battery, generator, household power source

How circuits work

CIRCUITS POWERED BY BATTERIES

Every battery has a positive terminal and negative terminal. The positive terminal is marked with a '+'. The negative terminal is marked with a '-'. A battery only provides power to a circuit when it is connected into the circuit.

ELECTRICITY AND ENERGY

Most people rely heavily on electricity, in the daily use of lights and electrical appliances. Electricity is a form of energy. It is a very useful form of energy because it can easily be sent down wires over long distances and can easily be turned into other types of energy.

Electrical energy can turn into kinetic energy, like the kinetic energy created by a fan or a battery-powered toy using an electric motor. Electrical energy can also turn into heat energy, like in a heater. Appliances always take electrical energy and turn it into at least two types of energy.

ACTIVITY 8.13: ENERGY TRANSFORMATIONS

Describe the transformation of energy in these appliances.

1 An electric toothbrush
2 An MP3 player
3 A light bulb
4 A hair dryer
5 A television

Electric power

Power is a measurement of how quickly energy is changed from one form to another. Power is measured in **watts** (W) or **kilowatts** (kW). One kW is the same as 1000 W. Light bulbs change electrical energy to light and heat energy. A bedside light bulb, of 25 W, changes only a small amount of electrical energy into heat and light energy every second. A heat lamp, of 250 W, converts 10 times the electrical energy than bedroom light bulbs do every second.

Most appliances have their power rating written on them. Power ratings tell you how much power an appliance uses when it is turned on.

power
The rate that energy is changed from one type to another; power is the energy changed divided by the time it takes for the energy to change

watt
Unit of measurement for power; one watt is the power when one joule of energy is changed every second

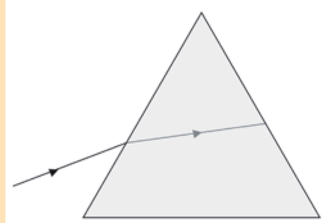
kilowatt
A unit of measurement for power; one kilowatt is the same as 1000 watts

SciFACTS

All appliances get warm because a flow of electrons always creates heat.

Figure 8.34: Desktop electric fans have a power rating ranging from about 20 W to 100 W

5 Copy and complete this diagram (right) of the separation of colours when white light refracts through a glass prism.



6 Discuss the differences between laser light and the light from light bulbs.

7 List five uses for lasers.

8 Put these types of light waves into order, from the shortest wavelength to the longest wavelength.

Ultraviolet
Microwaves
Visible light
X-rays
Radio waves
Infra-red

9 List three uses for light that is not visible.

10 Explain why a blue chair appears blue.

11 Explain why a white bird appears white.

12 Explain why a black pen appears black.

13 List the three primary colours of light.

14 A computer screen is showing a pink T-shirt. Which colour pixels will be glowing to make the pink colour?

15 A television screen is showing a yellow cartoon character. Which colour pixels will be glowing to make the yellow colour?

16 Name the two types of light-sensitive cells at the back of your eyes, and explain what each type of cell does.

SOUND

Sounds are caused by **vibrations**. We hear vibrations that have passed through a medium, generally air, into your ears. When you bang a drum the skin of the drum moves back and forth. This pushes the air next to the drum, making the air molecules move. Those molecules push the next layer of air molecules, and those push the next layer, and soon you have a wave of moving molecules. This wave of moving molecules is sound.

vibration
The back and forth movement of molecules that creates sound

Different musical instruments make different sounds by creating different vibrations. Guitars and violins have strings that move back and forth to make sound. Flutes and clarinets make a vibration of air inside them. You have flaps inside your throat called vocal cords that vibrate when you talk or sing.

Sound and light are both waves, but they have many differences. Light travels much faster than sound. Sound needs matter (atoms or molecules) to travel through, but light does not – light can travel through empty space.

that flows gives the sensation of how hot or cold it is. Think about being outside on a frosty day. If you were to touch a metal object with one hand and a wooden object with the other, the metal object would feel colder despite both objects being at the same temperature. They both feel cold because heat is transferring from your hand to the objects. The metal feels colder because the heat is transferring faster to the metal than it is to the wood.

There are three main methods by which heat is transferred. They are called conduction, convection and radiation and are explained below. Insulation prevents the transfer of heat, and is also explained.

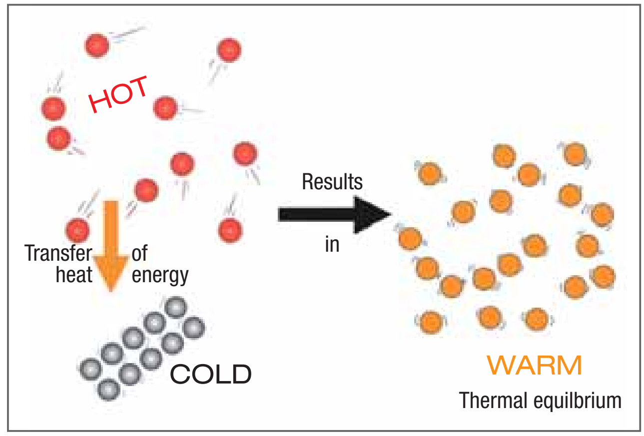


Figure 11.6: Transfer of energy from hot particles to cold particles results in thermal equilibrium

Conduction

Because the particles in a solid are bonded together, the main form of heat movement between them is by **heat conduction**. When one part of a solid is heated the particles in that part vibrate more. Some of this vibration is transferred to the surrounding particles, which in turn transfer some of the vibration onwards. **Electrical conductors**, such as metals, carry out this process easily.

Metals also tend to be good conductors of electricity. This is because they contain free electrons that are not bonded to atoms particularly well. These electrons are responsible for conducting electricity. When the metal gets hot these electrons also gain kinetic energy, which they transfer to other atoms and electrons throughout the metal, increasing the rate of heat conduction.

Glass and other **electrical insulators** are very poor conductors of heat and electricity. They do not have free electrons, and their atoms are not bonded together particularly strongly, which means that any vibration of an atom is not easily passed on to atoms next to it.

heat conduction
The process of particles passing on vibration energy

electrical conductor
A material, often metal, that easily allows the transfer of heat or electricity

electrical conduction
The process allowing movement of charge

electrical insulator
A material that does not easily allow heat or electricity to flow through it

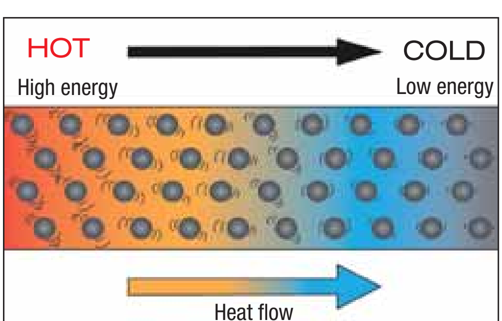


Figure 11.7: How heat is conducted through a solid

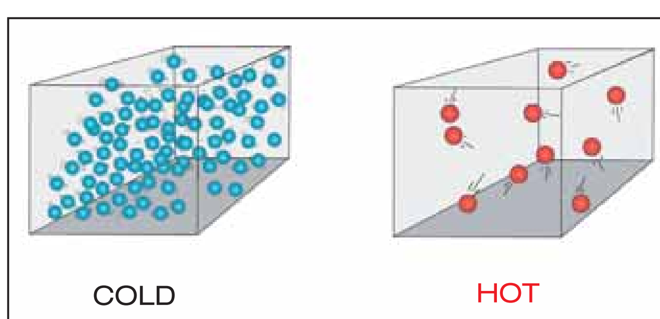


Figure 11.8: A substance when hot has less particles per unit than when it is cold

1 H Hydrogen							2 He Helium
3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon

Figure 11.32: Simplified periodic table of the first 10 elements (See the inside back cover for full table)

SciFACTS

The term 'periodic' is derived from the idea that, when arranged in columns by atomic mass, the properties of the elements are repeated periodically. Newspapers are sometimes referred to as periodicals as they appear on a regular, repeating basis.

Some properties of the periodic table are:

- Elements are arranged in rows called periods. Each element in a period has the same number of electron shells.
- Elements are arranged in columns called groups. Each element in a group has the same number of electrons in the outer shell, and so tend to react in similar ways. Groups 3 to 12 are missing from the simplified version of the periodic table shown in Figure 11.32 as none of the first 20 elements belong to these groups.
- Elements to the left of boron and silicon are metals. Elements to the right are non-metals. Boron and silicon are called metalloids – they have some properties of metals and some of non-metals.
- Elements in Group 17 are called halogens. They form salts when reacted with metals.
- Elements in Group 18 are called noble gases. They all have full outer electron shells and are almost completely unreactive.

ACTIVITY 11.15: RESEARCH PERIODIC TABLES

There are many more than one type of periodic table arrangement. Research some different shapes, such as the Alexander table, which is three-dimensional.

FORMATION OF IONS AND MOLECULES

So far we have looked at the structure and behaviour of atoms, and we have discussed how elements are made up of atoms of the same type. Ninety-two of these elements occur naturally on Earth, and another 10 have been synthesised in a laboratory

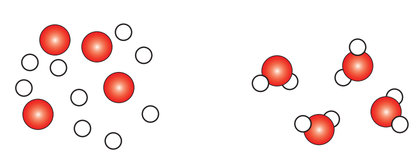


Figure 11.33: Atoms of two elements chemically bonding to form a molecule of a compound

ACTIVITY 11.16: PERIODIC TABLE, MOLECULES AND IONS

1 Copy this table of ions and then add elements from groups 1, 2, 16 and 17 of the periodic table (see the inside back cover) to complete it. Some of the more complex ions have already been added to help you. Remember that all elements in a particular group on the periodic table have the same number of electrons in the outer shell. Work out if it would make more sense for each element to lose or gain electrons in order to have a full or empty outer shell.

3+	2+	1+	1-	2-	3-
Al^{3+}					
Fe^{3+} Iron	Mg^{2+}		Cl^{-} Chloride		P^{3-} Phosphide
		Na^{+}	OH^{-} Hydroxide	CO_3^{2-} Carbonate	PO_4^{3-} Phosphate
	Cu^{2+} Copper		NO_3^{-} Nitrate	SO_4^{2-} Sulfate	
	Zn^{2+} Zinc	NH_4^{+} Ammonium	HCO_3^{-} Bicarbonate		
	Pb^{2+} Lead	Ag^{+} Silver			

2 Use the periodic table and the table of ions from question 1 to answer the following.

a Elements that form ions with a 1+ charge all belong to which group?

b Elements that form ions with a 1- charge all belong to which group?

c Elements that form ions with a 2+ charge all belong to which group?

d Elements that form ions with a 2- charge all belong to which group?

e Why are there no elements from group 18 in the table of ions?

Ionic and covalent bonds

Molecules are formed from two main types of bond: ionic bonds and covalent bonds.

electrolysis
The process of separating a substance by passing an electrical current through it

IONIC BONDS

When an ionic bond is made, one atom loses electrons to another. This means they are no longer neutral atoms, but oppositely charged ions. Opposite charges attract, so a new compound is formed as the ions are attracted to one another.

Because they are held together by electrical charge, ionic compounds can be separated using electricity. Separation of ions by this method is called **electrolysis**.

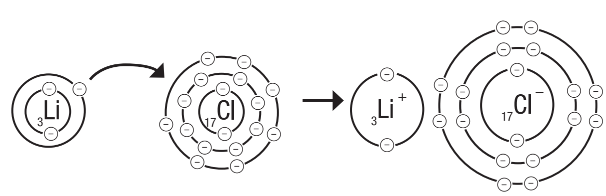


Figure 11.37: Lithium atom and chlorine atom forming an ionic bond

cation
A positively charged ion that is attracted to the negatively charged cathode in electrolysis

cathode
A negatively charged electrode

anion
A negatively charged ion that is attracted to the positively charged anode in electrolysis

anode
A positively charged electrode

Positive ions are called **cations** – they are attracted to the negative **cathode** during electrolysis. Similarly, negative ions are called **anions** – they are attracted to the positive **anode** during electrolysis. In the example shown in Figure 11.38, copper metal can be seen forming on the negative cathode, and bubbles of chlorine gas can be seen forming on the positive anode.

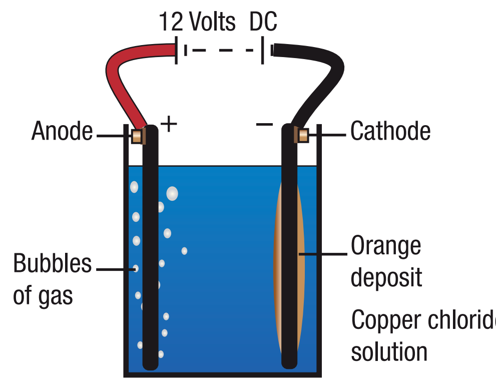


Figure 11.38: Separation of ions in copper chloride by electrolysis

Ions tend to form compounds with no overall charge. For example, sodium and chlorine react to form sodium chloride (table salt). Sodium forms ions with a charge of 1^+ and chlorine forms ions with a charge of 1^-. So one ion of sodium and one ion of chlorine will have an overall charge of zero, giving the molecular formula NaCl.

Similarly, magnesium and chlorine react to form magnesium chloride. Magnesium forms ions with a charge of 2+, so two Cl^- ions are needed to balance this. The molecular formula for magnesium chloride is $MgCl_2$.

Be careful with complex ions and brackets For example, magnesium reacts with nitrate ions (NO_3^-) to form magnesium nitrate $Mg(NO_3)_2$. This molecular formula shows that there are two nitrate ions in one molecule of magnesium nitrate.

Since there are only two parts of an ionic compound, one positive and one negative, it is very straightforward to work out the molecular formula of their molecules. Remember that the molecule must have an overall charge of zero.

Example 3

Step 1: Identify the positive and negative ions in the compound.

e.g. Magnesium chloride is made from positive magnesium ions (Mg^{2+}) and negative chloride ions (Cl^-).

Step 2: Add more negative or positive ions so that the overall charge is zero.

e.g. Mg^{2+} requires two negative charges to balance, so two Cl^- ions will be needed.

Step 3: Write the molecular formula for the molecule using subscripts to show if there is more than one.

e.g. $MgCl_2$ (there is no need to put a $_1$ by magnesium)

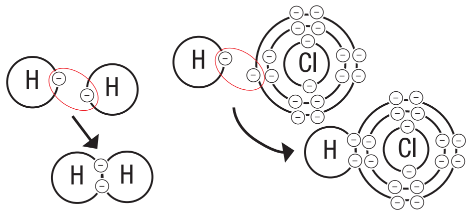


Figure 11.39: Two hydrogen atoms forming a covalent bond, and a hydrogen and chlorine atom forming a covalent bond

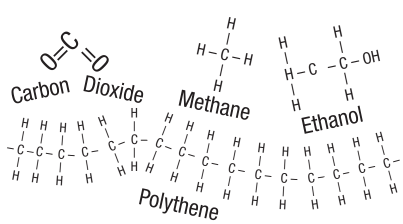


Figure 11.40: Structural formula of carbon dioxide, methane, ethanol and polythene

polar molecule
Molecule that has ends of different charge

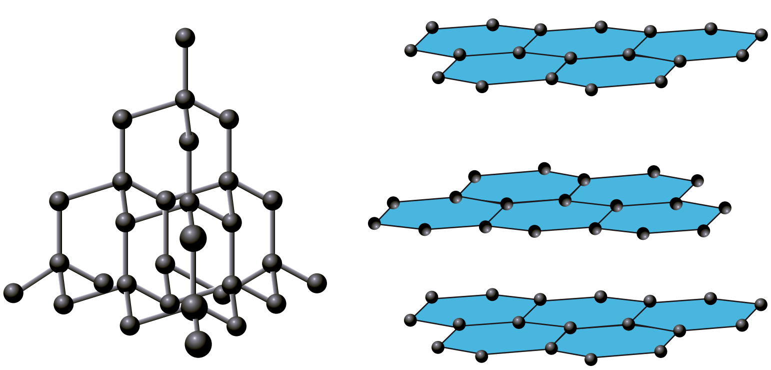
such as chlorine, in this case forming hydrogen chloride. Note that neither atom has lost nor gained electrons, as in ionic bonding, but rather the electrons are being shared.

Carbon atoms form covalent bonds with atoms of other elements. They also bond easily to other carbon atoms. Carbon is known to form over 10 million different compounds. For example, most of the fuels and plastics that we use are carbon compounds formed from carbon and hydrogen. Despite this, carbon is very unreactive on its own.

As discussed in chapter 10, to represent compounds we can use structural formulas, in which each line is one covalent bond.

Pure carbon comes in a variety of arrangements depending on how the covalent bonds have formed. Each form has unique properties. For example, diamond is clear, very hard and not a good conductor of electricity. Graphite is black, very soft (it is used to make the 'lead' in pencils) and a good conductor of electricity. Black carbon powder is the amorphous (without definite shape or structure) form of carbon.

Some covalent compounds, such as water, form **polar molecules** (where the ends of these molecules have a different charge). This happens when electron sharing is not even. As a result it becomes more negatively charged, making the other molecule more positive. The polar nature of water molecules is one reason for water's unique properties. Since no two non-metal elements have exactly the same attraction for electrons, they all form polar compounds.



(a) Diamond (b) Graphite

Figure 11.41: Arrangement of carbon atoms in diamond and graphite

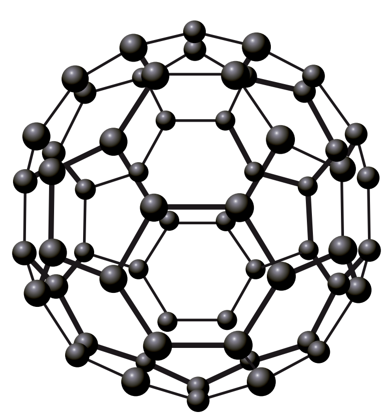


Figure 11.42: Carbon can also form hollow ball-shaped molecules nicknamed 'buckyballs'.

Periodic Table

Period / Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16	9 F 19	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52	25 Mn 54.94	26 Fe 55.85	27 Co 58.47	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.9	36 Kr 83.8
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197	80 Hg 200.5	81 Tl 204.4	82 Pb 207.2	83 Bi 209	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rq (272)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (292)	117 Uus 0	118 Uuo 0
6				58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173	71 Lu 175	
7				90 Th 232	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)	

- Nonmetals
- Alkali metals
- Alkaline Earth metals
- Transition elements
- Other metals
- Metalloids
- Halogens
- Noble gases
- Lanthanides
- Actinides

Nonmetals
1 H Hydrogen
6 C Carbon
7 N Nitrogen
8 O Oxygen
15 P Phosphorus
16 S Sulfur
34 Se Selenium

Alkali Metals
3 Li Lithium
11 Na Sodium
19 K Potassium
37 Rb Rubidium
55 Ca Caesium
87 Fr Francium

Alkaline Earth Metals
4 Be Beryllium
12 Mg Magnesium
20 Ca Calcium
38 Sr Strontium
56 Ba Barium
88 Ra Radium

Transition Elements
21 Sc Scandium
22 Ti Titanium
23 V Vanadium
24 Cr Chromium
25 Mn Manganese
26 Fe Iron
27 Co Cobalt
28 Ni Mickel
29 Cu Copper
30 Zn Zinc
39 Y Yttrium
40 Zr Zirconium
41 Nb Nobium
42 Mo Molybderium
43 Tc Technetium
44 Ru Ruthenium
45 Rh Rhodium
46 Pd Palladium
47 Ag Silver
48 Cd Cadmium
72 Hf Hafnium
73 Ta Tantalum
74 W Tungsten
75 Re Rhenium
76 Os Osmium
77 Ir Iridium
78 Pt Platinum
79 Au Gold
80 Hg Mercury
104 Rf Rutherfordium
105 Db Dubnium
106 Sg Seaborgium
107 Bh Bohrium
108 Hs Hassium
109 Mt Meitnerium
110 Ds Darmstadtium
111 Rg Roentgenium
112 Uub Ununbium (Copernicium)
113 Uut Ununtrium
114 Uuq Ununquadium
115 Uup Ununpentium
116 Uuh Ununhexium
117 Uus Ununseptium
118 Uuo Ununoctium

Other Metals
13 Al Aluminum
31 Ga Gallium
49 In Indium
50 Sn Tin
81 Tl Thallium
82 Pb Lead
83 Bi Bismuth

Metalloids
5 B Boroni
14 Si Silicon
32 Ge Germanium
33 As Arsenic
51 Sb Antimony
52 Te Tellurium
84 Po Polonium

Halogens
9 F Fluorine
17 Cl Chlorine
35 Br Bromine
53 I Iodine
85 At Astatine

Noble Gases
2 He Helium
10 Ne Neon
18 Ar Argon
36 Kr Krypton
54 Xe Xenon
86 Rn Radon

Lanthanoids
57 La Lanthanum
58 Ce Cerium
59 Pr Praseodymium
60 Nd Neodymium
61 Pm Promethium
62 Sm Samarium
63 Eu Europium
64 Gd Gadolinium
65 Tb Terbium
66 Dy Dysprosium
67 Ho Holmium
68 Er Erbium
69 Tm Thulium
70 Yb Ytterbium
71 Lu Lutetium

Actinides
89 Ac Actinium
90 Th Thorium
91 Pa Protactinium
92 U Uranium
93 Np Neptunium
94 Pu Plutonium
95 Am Americium
96 Cm Curium
97 Bk Berkelium
98 Cf Californium
99 Es Einsteinium
100 Fm Fermium
101 Md Mendelevium
102 No Nobelium
103 Lr Lawrencium