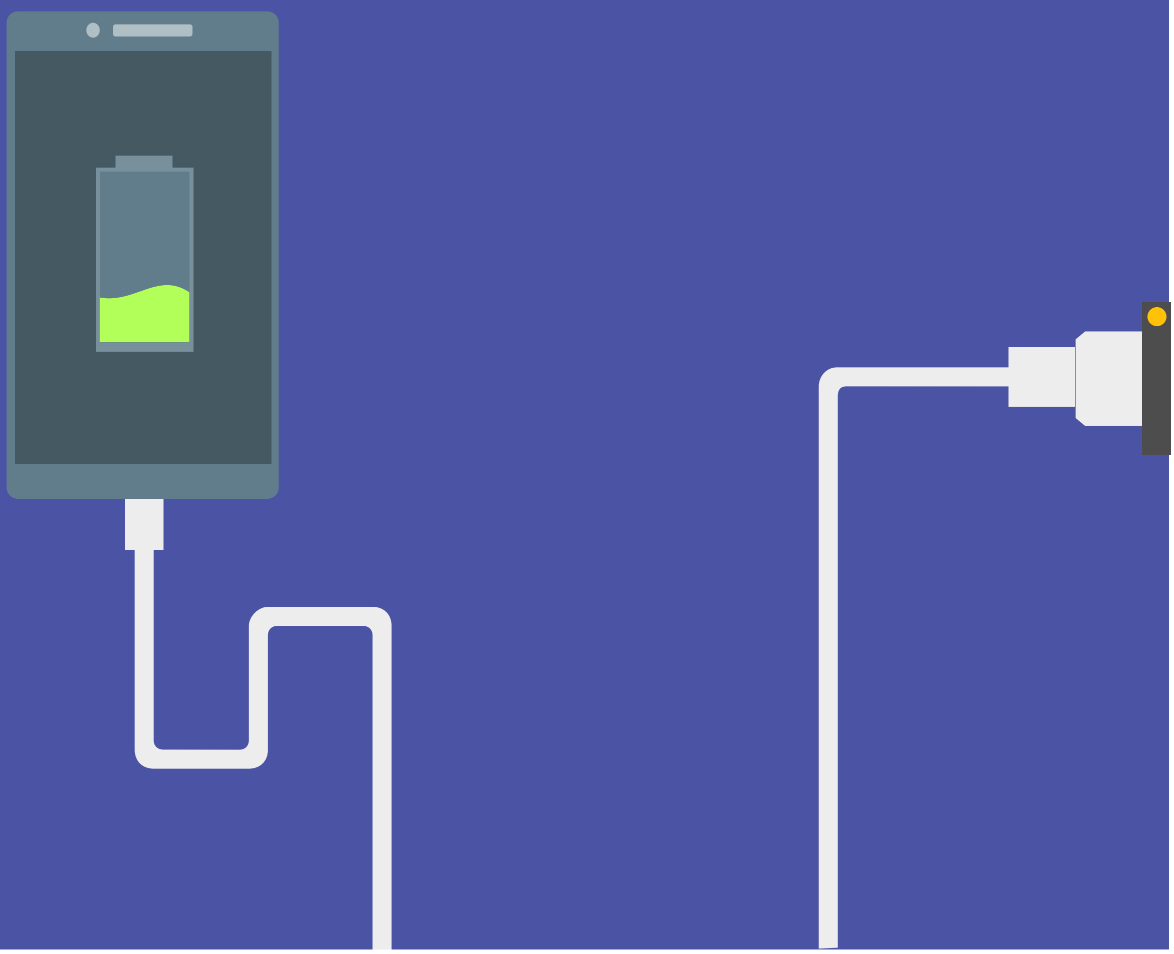
Modern living and energy (Unit 1.1)

Underpinning energy concepts (specification 1.1.1)



Modern living and energy (Unit 1.1)

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ENERGY AND EFFICIENCY

It is important for us to understand energy transfer if we are to efficiently generate or use energy in the home. In this topic, we will aim to understand some key concepts which can then be applied to sustainable energy generation and use.

Energy

Remember:
- **energy cannot be created or destroyed**
- energy can be transferred usefully, stored or dissipated

Forms of energy

You should be able to recognise the main forms of energy. Some important forms of energy include:

- magnetic
- kinetic (movement energy)
- heat (thermal energy)
- light
- gravitational potential
- chemical
- sound
- electrical
- elastic potential
- nuclear

Efficiency

When we generate electricity or use energy in some way, the process will involve the transfer of energy. However not all of this energy is transferred usefully.

The **efficiency** of an energy transfer is the percentage of the energy transferred to useful energy output.

Whenever energy is transferred in a process, some energy is lost. For example if we generate electricity from coal only some of the energy stored in the coal is transferred to the electricity. The rest of the energy is wasted e.g. lost as heat energy to the surroundings.

Efficiency can be calculated using

Foundation tier

These equations will be given to you, if you need to use them in an exam.

$$\%\ \text{efficiency} = \frac{\text{energy usefully transferred}}{\text{total energy supplied}} \times 100$$

Or by using

$$\%\ \text{efficiency} = \frac{\text{power usefully transferred}}{\text{total power supplied}} \times 100$$

For example

In a coal-fired power station, only 400J was transferred to generate electricity for every 1 000 J of energy stored in coal. 600 J of energy was wasted as heat energy to the surroundings. We can use the equation below to calculate the efficiency of the process:

$$\% \text{ efficiency} = \frac{600}{1\,000} \times 100$$

$$\text{efficiency} = 60$$

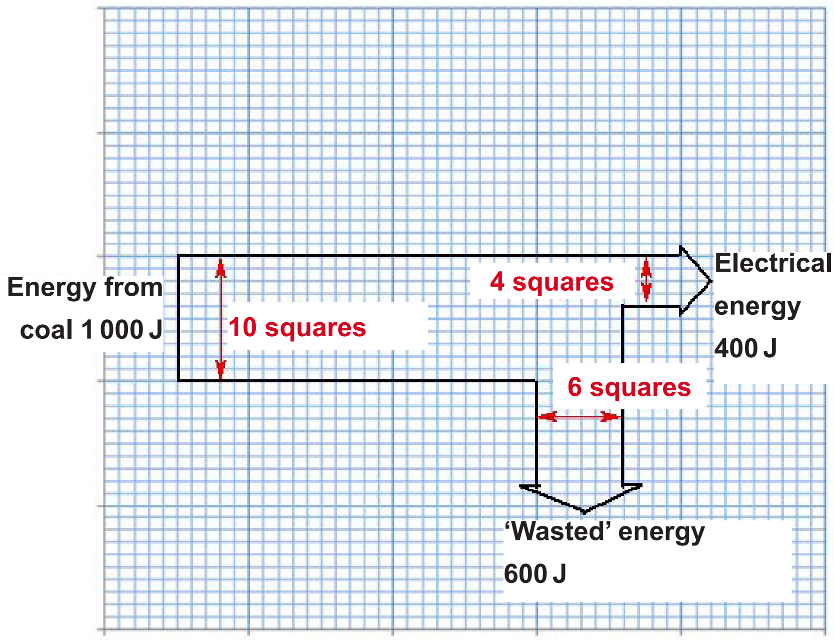
Coal fired power statio
eye35.pix / Alamy Stock Photo

In a coal powered station chemical energy stored in coal is used to generate electricity. Not all that energy is converted into electricity. Some of the energy is lost to the surroundings as heat energy.

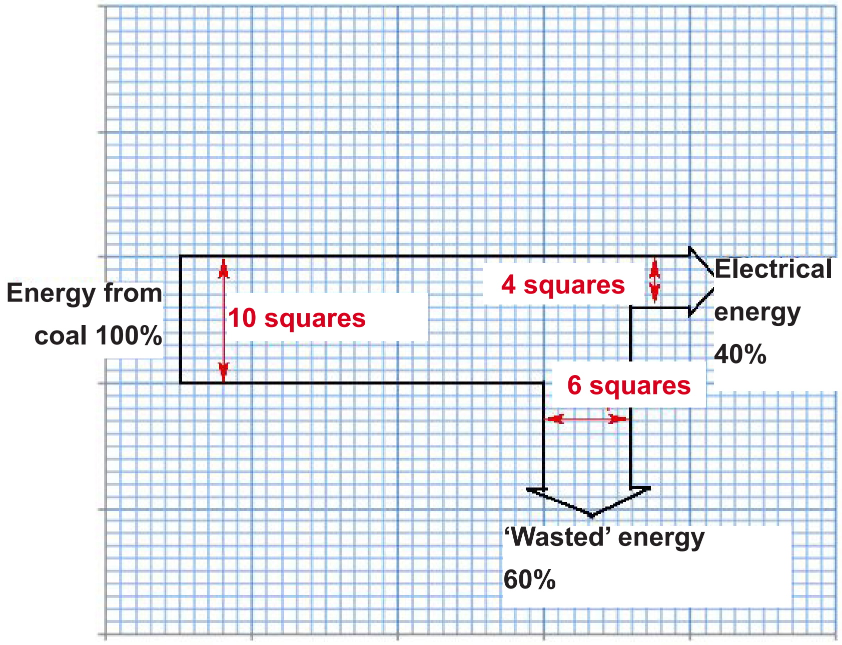
Sankey diagrams

Sankey diagrams summarise all the energy transfers taking place in a process.

These diagrams are drawn to scale. This Sankey diagram shows the energy transferred from coal to energy as electricity for the power station we described on the previous page.



You may also see the diagram drawn showing the percentage transfer of energy.



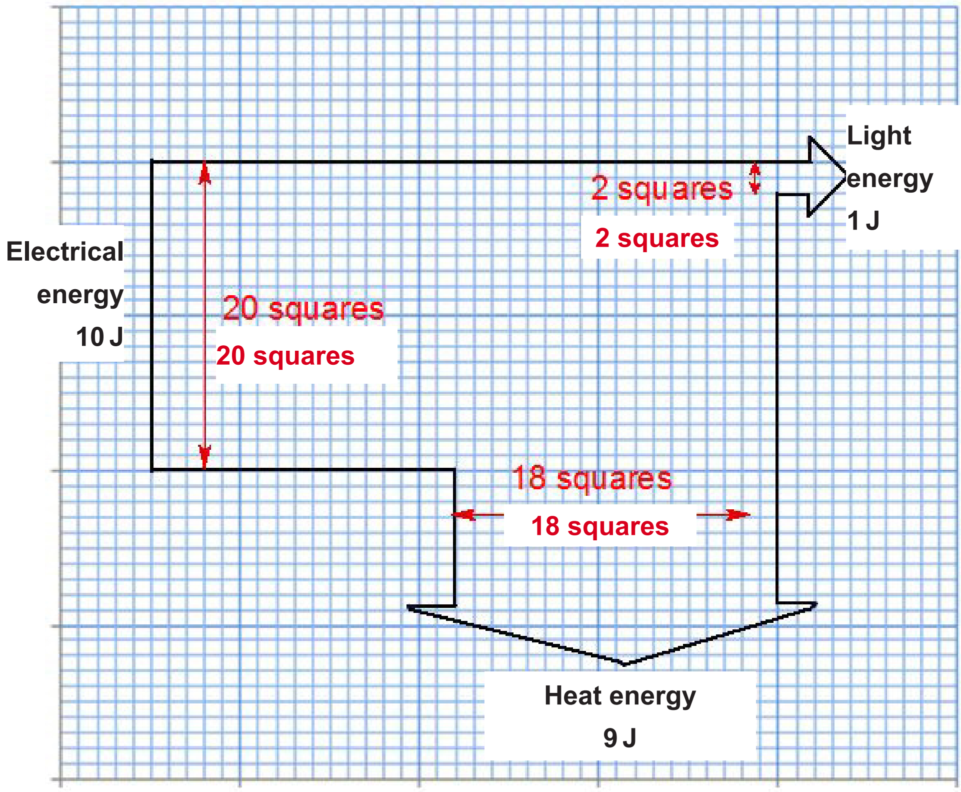
We can draw Sankey diagrams for any process.

Make sure you can draw a Sankey diagram and use a Sankey diagram to find information.

A Sankey diagram for a filament lamp is shown below .

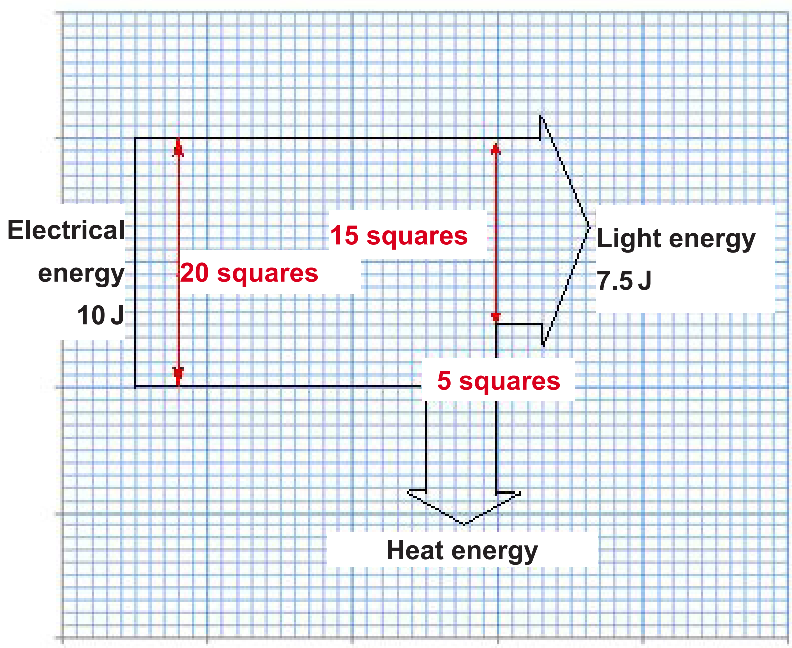
For every 10 J of electrical energy supplied to the lamp only 1 J is transferred to the surroundings as light energy. The remainder, 9 J (10 J – 1 J) is transferred to the surroundings as heat energy.

The energy transfer to light energy is the useful transfer. The rest is 'wasted': it is eventually transferred to the surroundings, making them warmer. This 'wasted' energy eventually becomes so spread out that it becomes less useful.



TEST YOURSELF

1. A Sankey diagram of an LED lamp is shown below. Calculate the efficiency of the lamp and select the correct answer below.



A 7.5%

B 75%

C 25%

D 2.5%

Energy transfer calculations

An electric current is the movement of a charge through an electrical conductor. When an electric current flows in a circuit, energy is transferred from the power supply to the components in the circuit.

The power of an electrical appliance tells us how much electricity it transfers in one second. Power is measured in watts, W, where

1 W = 1 J/s

Energy is measured in joules, J.

The rate of energy transfer is called the **power.**

Power can be calculated using the equation:

$P = V \times I$

power (W) = potential difference (*V*) x current (*A*)

The amount of electrical energy transferred to an appliance depends upon the power rating of the appliance and the time for which it is switched on.

Energy transferred from electricity can be calculated using:

$E = P \times t$

energy(J) = power(W) × time(s)

or

energy(kWh) = power(kW) × time(hours)

Remember your units:

1 kW = 1 000 W

1 kJ = 1 000 J

1 hour = 60 × 60 = 3 600 seconds

Watch your units when you use this equation

Foundation tier

$P = V \times I$ or $E = P \times t$ will be given to you if you need to use them in the exam

PAYING FOR ELECTRICITY

When we pay for our electricity we pay for the energy used. The units on the electricity bill are measured in kilowatt hours. We are then charged for each unit of electricity used.

total cost = number of units used (kWh) × cost per unit

Examples of electrical energy calculations

Example 1

A 2 500 W electrical fire is switched on for 4 hours.

Calculate the energy used in that time and the cost of using the appliance if 1 unit costs 9 pence.

> Make sure you use units correctly.
>
> You must make sure that:
>
> - time is measured in hours
> - power is in kilowatt hours

Answer

Now $E = P \times t$ where:
E is the energy transferred in kilowatt hours, kWh
P is the power in kW
t is the time in hours.

Power = $\frac{2\,500}{1\,000}$ W = 2.5 kW

Energy used = 2.5 × 4 = **10 kWh**
cost = 10 × 9 = **90 pence**

Example 2

A 2.0 kW kettle is used for an average of 45 minutes each day.

Calculate the energy used by the kettle each day.

Calculate how much the kettle cost to use during May 2016.

Cost of 1 unit in May 2016 = 10 pence.

Make sure you use units correctly.

In this case we need to convert the time into hours

The answer will be in **kilowatt hours.**

May 2016

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Answer

Now $E = P \times t$ where:
E is the energy transferred in joules, kWh
P is the power in watts, kW
t is the time in hours
The time the kettle is used each day = 45/60 = 0.75 hours
Energy used each day = 2.0 × 0.75 = **1.5 kWh**
There are 31 days in May so the electricity used in May = 31 × 1.5 = 46.5 units
Cost of using kettle during May 2016 = 46.5 × 10 = 465 pence = £4.65

Example 3

A torch with a 4.5 V battery has a current of 3.0 A.

Calculate the power of the torch using the equation:

$P = I \times V$

$P = 3.0 \times 4.5$

$P = 13.5$ W

Modern living and energy (Unit 1.1)

Underpinning energy concepts (specification 1.1.1)

TEST YOURSELF

P is the power in watts (W); I is the current in amps (A); V is the voltage in volts (V)

1. Energy transferred from electricity can be calculated using:

$$E = P \times t$$

If energy is measured in joules what should the units of power and time be measured in?

A power in kilowatts and time in hours
B power in kilowatts and time in seconds
C power in watts and time in seconds

2. If energy is measured in units of kilowatt-hour what should the units of power and time be measured in?

A power in kilowatts and time in hours
B power in kilowatts and time in seconds
C power in watts and time in seconds

3. Complete the following sentence by underlining the correct word in the brackets.
Power is measured in (**watts / kilowatt-hours / kilograms**).

1 W equals 1 (**J/s / Js / N**).

Modern living and energy (Unit 1.1)

Underpinning energy concepts (specification 1.1.1)

SUSTAINABILITY AND CARBON FOOTPRINT

Our use of energy resources can have an impact on the environment. It is useful to think how we effect the environment in terms of sustainability and our carbon footprint.

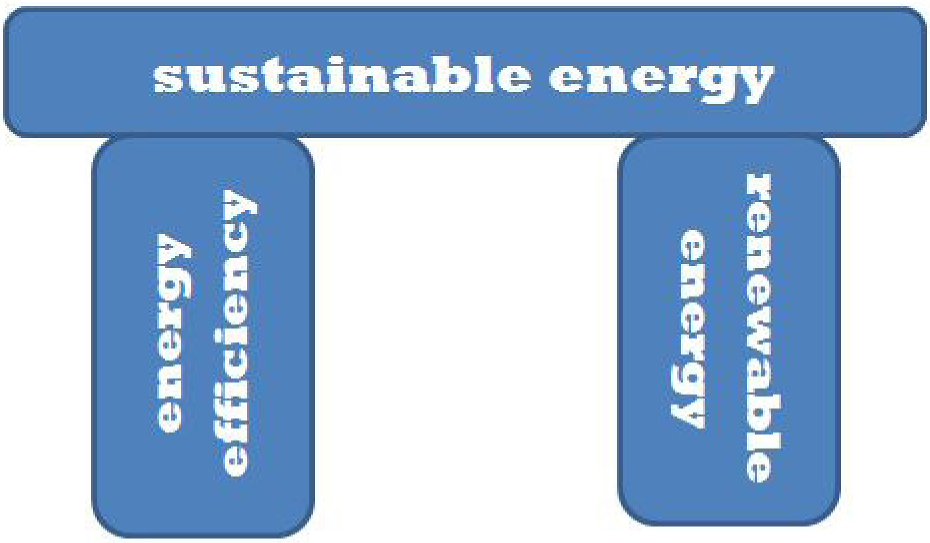
Sustainability and energy

Sustainability (in the context of energy) is about using energy resources in such a way that we do not put at risk the ability of people in the future to meet their own energy needs.

If an activity is said to be sustainable, it should be able to continue forever. Living sustainably is about living within the means of our environment and ensuring that our lifestyle doesn't harm other people.

Sustainable energy includes both energy efficiency and renewable energy.

Both energy efficiency and renewable energy can be thought of as the twin pillars of sustainable energy.



Modern living and energy (Unit 1.1)

Underpinning energy concepts (specification 1.1.1)

Sustainability means that we use resources while remembering the future generations that follow us. We can be sustainable by:

- using energy more efficiently.
- reducing our dependence on non-renewable energy resources such as fossil fuels. All renewable energy sources like solar, wind, geothermal, hydropower and ocean energy are sustainable.

Sustainable energy is **different** to low-carbon energy, which is sustainable only in the sense that it does not add to the CO_2 in the atmosphere.

We will comment further on sustainability in **topic 1.1.2.**

Carbon footprint

It is feared that the climate is changing due to man-made emissions of greenhouse gases into the atmosphere. Greenhouse gases trap energy in the Earth's atmosphere so causing the atmosphere to warm. Gases such as carbon dioxide and methane are greenhouse gases.

Traffic
Jupiterimages / gettyimages

The **carbon footprint** is a measure of the impact of activities which release greenhouse gases on the environment.

It calculates all the greenhouse gases (e.g. methane and carbon dioxide) we are expected to produce in all our activities and measures them in units of carbon dioxide.

Almost all our activities have a carbon footprint. Sometimes it is obvious that there is a carbon footprint. If we came to school by car or on a bus, fossil fuel was burnt producing carbon dioxide.

Sometimes it may be less obvious that there is a carbon footprint.

Tap water
naumoid / gettyimages

Every time we run a tap there is a carbon footprint. Why? Energy is needed to make water pipes to deliver our water. Water pipes also need to be put in place. Roads may need digging up to repair water mains. Energy is needed to clean the water etc. If we are using energy there will always be a carbon footprint.

Energy production always has a carbon footprint, no matter what form of energy we produce.

Wind turbines
leighcol / gettyimages

For example, a wind turbine produces about 5 g of CO_2 for every 1 kWh of electricity produced. Why? We need to construct the wind turbines using steel which is an energy intensive process, the turbines need transporting by lorry to be put in place and there will need to be maintenance.

Carbon dioxide equivalent

Carbon dioxide is not the only greenhouse gas. When we measure our carbon footprint we need to measure other greenhouse gases as well. The total greenhouse gas emissions are measured in units of **mass equivalent of carbon dioxide** (kgCO2eq).

Notice that we do not subscript the ‘2’ in the unit for mass equivalent of carbon dioxide.

Not all gases have the same greenhouse effect. To calculate the carbon footprint we need to convert the mass of a greenhouse gas, such as methane, into the mass of carbon dioxide that causes the same greenhouse effect. The following table compares three greenhouse gases.

gas	carbon dioxide equivalent
carbon dioxide (CO_2)	1
methane (CH_4)	21
nitrous oxide (N_2O)	298

The carbon dioxide equivalent tells us that releasing 1 kg of CH_4 into the atmosphere is equivalent to releasing 21 kg of CO_2.

Releasing 1 kg of N_2O into the atmosphere is about equivalent to releasing 298 kg of CO_2.

We can convert the mass of any gas into the carbon dioxide equivalent using:

mass equivalent of carbon dioxide (kgCO2eq) = (mass of gas) × (global warming potential)

Methane is a gas produced when cows belch.

To help combat methane production, research is being conducted into breeding cows that produce less methane.

Cow
Axel Ellerhorst / gettyimages

Example of a calculation involving carbon footprint

In 1980, Australian dairy cows produced about 2 800 litres of milk each year. 33 g of methane was released by the cow for each litre of milk the cow produced.

(a) Calculate the total amount of methane produced each year.

(b) Calculate the mass equivalent of carbon dioxide in units of kgCO2eq using the equation:

mass equivalent of carbon dioxide (kgCO2eq) = (mass of gas) × (global warming potential)

[The global warming potential of methane is 21]

Answer

(a) Total amount of methane produced = 33 × 2 800 = 92 400 g
Change units 92 400/1 000 = 92.4 kg methane

(b) mass equivalent of carbon dioxide = (mass of gas) × (global warming potential)
mass equivalent of carbon dioxide = 92.4 × 21
= **1 940.4 kgCO2eq**

TEST YOURSELF

1. State two pillars of sustainable energy.

A fossil fuels and energy efficienc
B renewable energy and energy efficienc
C renewable energy and the carbon footprint

2. Select the units of mass equivalent carbon dioxide.

A kgCO2
B kCO2eq
C kgCO2eq

3. Select the correct statement from below given:

The carbon dioxide equivalence of methane is 21 and that of nitrous oxide is 298.

A The carbon footprint of 1 kg methane is greater than 1 kg nitrous oxide
B The carbon footprint of 1 kg nitrous oxide is greater than 1 kg methane
C The carbon footprint of 1 kg methane is about the same as 1 kg nitrous oxide

PRACTICE QUESTIONS

1. The information below is taken from George's satellite box.

Mains	AC	220-240 V	50-70 Hz
Power consumtion	ON	45 W	
	Stand-by	30 W	

The following conversion factor is taken from a government website.

Fuel	quantity consumed	mass CO_2 produced
Grid Electricity	1 kWh	0.5246 kg

(i) State the relationship between power and the energy transferred by George's satellite box. **[1]**

....

(ii) On average George uses his satellite box for 3 hours a day to watch television.

I Show that the satellite box uses a total of 0.765 kWh of electricity each day if George puts the satellite box on standby for the remaining 21 hours.

You must show your workings.

[2]

II If George leaves the satellite box 'on' all day rather than switching it to standby he will use 1.080 kWh of electricity each day.

Calculate how much unnecessary CO_2 George will produce each year by not switching his satellite box to stand-by.

You must show your workings.

[4]

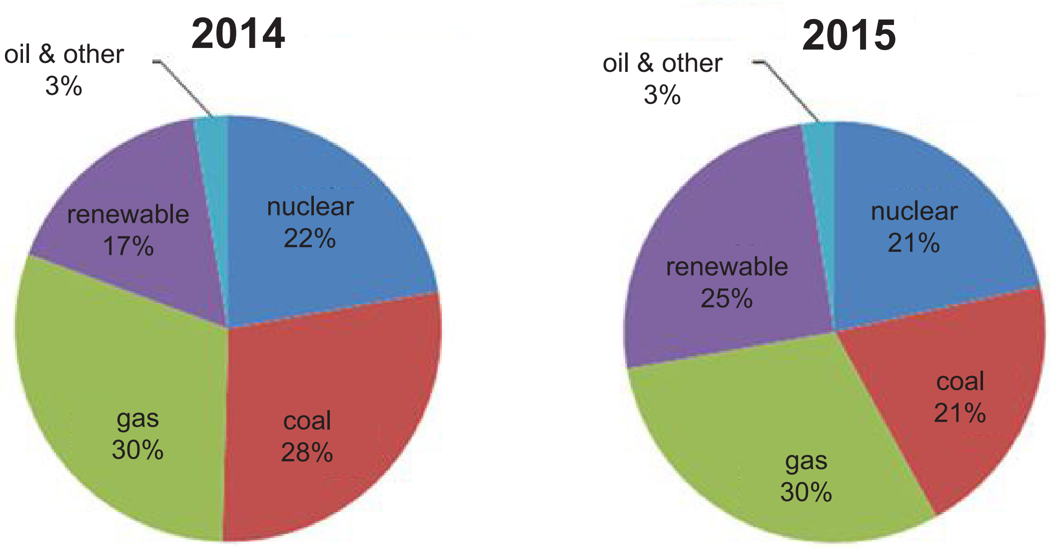
Modern living and energy (Unit 1.1)

Generating electricity (specification 1.1.2)

NON-RENEWABLE AND RENEWABLE SOURCES

Generating electricity from non-renewable sources

Most of the electricity generated in the UK still comes from power stations which burn fossil fuels (coal, oil and natural gas). Nuclear power also makes an important contribution. The pie charts below compare the sources from which electricity was generated in the second quarter of 2014 and 2015.



The pie charts show that there is a move away from using coal which has a high carbon footprint. The UK government has committed itself to close all coal-fired power plants by 2025, the firs major country to do so. It intends to fill the capacity gap largely with new gas and nuclear plants.

Coal fired power statio
nico_65 / gettyimages

Modern living and energy (Unit 1.1)

Generating electricity (specification 1.1.2)

The following table summarises some advantages and disadvantages of using fossil fuels to produce electricity.

Advantages	Disadvantages
They give a large amount of energy from a small amount of fuel. Fuels are readily available. If you need more energy, you just burn more fuel. They are relatively cheap.	They are **non-renewable.** Long term use is not going to be sustainable. They cause pollution. Burning a fossil fuel produces carbon dioxide. Carbon dioxide is a greenhouse gas and so contributes to our **carbon footprint.** Other pollutants include sulfur dioxide which contributes to acid rain unless it is removed from the waste gas emissions. Power stations burning fossil fuels use water as a coolant and may return warm water into a river. This decreases the amount of dissolved oxygen in the river.

Nuclear energy is also used to generate electricity. Although it has a low carbon footprint, it has the disadvantage of producing radioactive waste which lasts a long time.

Carbon footprint of non-renewable sources energy

	Nuclear	Coal-fire	Oil-fire	Gas turbine	CCGT*
Carbon footprint gCO2eq/kWh	5	1 000	650	1 000	500

*CCGT Is an efficient method of producing electricity using gas

Generating electricity from renewable energy source

There has been a growth in renewable technologies to generate electricity. Renewable energy sources quickly replenish themselves and can be used again and again. The following table lists some advantages and disadvantages of renewable sources of energy to generate electricity.

Type of energy	More information	Advantages	Disadvantages
wind	Wind turbines are used to convert the kinetic energy from wind into electrical energy.	Potentially infinite resource. No air pollution once installed.	Costly. Do not produce power if the wind speed is too low or too high. Unsightly. Some people complain about noise from wind farms.
solar	Energy from sunlight is captured and converted into electricity.	Potentially infinite resource. No air pollution once installed.	Costly. Do not produce electricity at night.
tidal	The movement of tides drives turbines. A tidal barrage needs to be built.	Ideal for an island. Potential to generate a lot of energy. Tidal barrage can act as a bridge.	Construction of a barrage is extremely costly. May prevent flow of sewage out to sea.

wave	The movement of seawater drives a turbine.	Ideal for an island country.	Costly.
hydroelectric	Energy harnessed from the movement of water.	Creates water reserves as well as energy supplies.	Costly to build. Local communities and landscapes may need to be flooded. Dams have major ecological impacts.
biomass	An example is oilseed rape which produces oil.	Cheap source of energy. Sustainable energy source.	Land is no longer available for growing food.
wood	Obtained from felling trees which are then burned.	Cheap source of energy. It is carbon neutral and sustainable if the trees are replanted.	Atmospheric pollutants formed by burning wood.
waste	Waste is burned to produce energy which can be used to generate electricity.	Less waste to go into landfill sites.	Pollutants are formed.

Which is the best way to generate electricity?

You need to be able to use information to make decisions about the best way to generate electricity. There is no perfect method for generating electricity. When you deal with information of this type you will need to compare the pros and cons of each.

You need to think about:

- sustainability
- carbon footprint
- environmental impact
- lifetime
- power produced

You will normally be given data in a question that requires you to make comparisons.

For example, you could be asked to compare the two methods of energy production:

Method of energy production	Onshore wind turbine	Nuclear power station
Overall cost of generating electricity (p/kWh)	5.6	2.8
Maximum power output (MW)	2	3 600
Lifetime (years)	15	45
Waste produced	none	radioactive waste
Lifetime carbon footprint (gCO_2/kWh)	4.9	5

In such a case, you could structure your answer by looking at the advantages that nuclear power has over wind turbines:

Cost	Nuclear power is half the cost of that produced by wind turbine.
Power output	You need 3 600/2 = 1 800 wind turbines to generate the same amount of power as a nuclear power station.
Lifetime	The lifetime of nuclear power station is three times that of the wind turbine.

On the other hand:

Wind turbines do not produce waste whereas there is radioactive waste produced by nuclear power stations which will last a very long time.

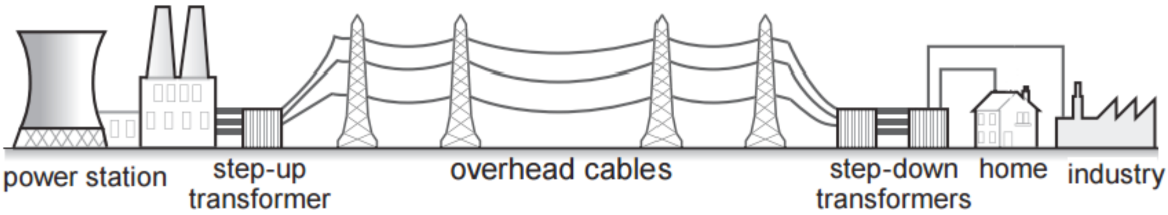
The carbon footprint is not decisive in this case. Both methods have very similar carbon footprints. That of wind turbines is slightly better.

THE NATIONAL GRID

In the UK, electricity is transferred from the power station to consumers by the National Grid.

The **National Grid** is a network that connects all generators of electricity, such as power stations, with all users, such as homes, offices and factories.

Power lines across the country connect together all the power stations with all the people who use electricity.



UK National Grid

National grid: Transporting electricity efficientl

Whenever a current flows through a wire some of the energy is lost as heat. The higher the current, the more heat is lost. In order to reduce these losses, the **National Grid** transmits electricity at a **low current** and a **high voltage.**

Power stations produce electricity at 25 000 V. Electricity is sent through the National Grid cables at 400 000 V, 275 000 V and 132 000 V.

Transformers are used to change the size of the voltage. **Step-up transformers** are used at power stations to produce the very high voltages needed to transmit electricity through the National Grid power lines (transmission lines).

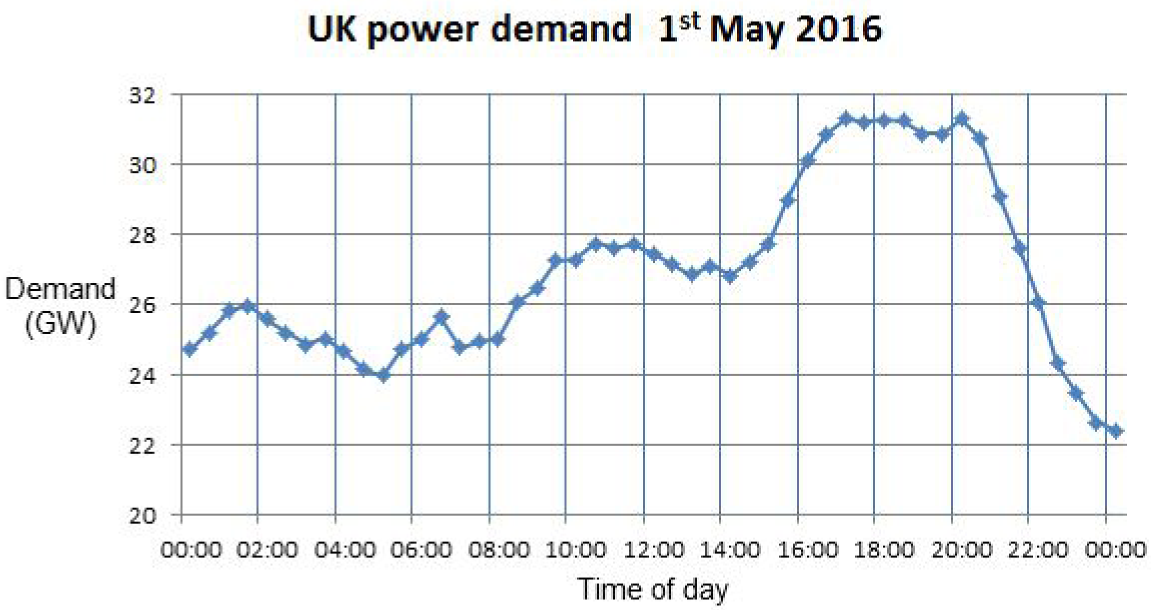
These high voltages are too dangerous to use in the home, so **step-down transformers** are used locally to reduce the voltage to safe levels.

The voltage of household electricity is about 230 V.

Responding to demand

Electricity cannot be stored; it has to be generated as it is needed. In Britain, it is the job of the National Grid to balance the supply and demand of electricity. Demand varies greatly during the day, and throughout the year.

Demand will depend upon what people are doing at any point in the day, how cold it is, even whether there is a big sporting event on television.



The grid controllers need to ensure that sufficient power stations are up and running, ready to meet any increase in demand. This makes forward planning important.

Since electrical power cannot be stored in large quantities most fossil fuelled and nuclear power stations are run continuously, to provide a minimum amount of power to the National Grid. This is called the **base load.**

In order to respond to changes the National Grid can draw on different sources of power but each source has a different start up time, reliability and cost; they also have a different carbon impact.

Modern living and energy (Unit 1.1)

Generating electricity (specification 1.1.2)

The most flexible generation is known as ‘pumped storage’. Pumped storage works in a similar way to hydroelectricity but uses electricity at times of low demand to pump water up into a reservoir. This water can then be used to generate electricity at times of high demand. This method of generating electricity is limited so it has to be used along with coal and gas fired power stations.

The least flexible is nuclear and the least predictable is wind.

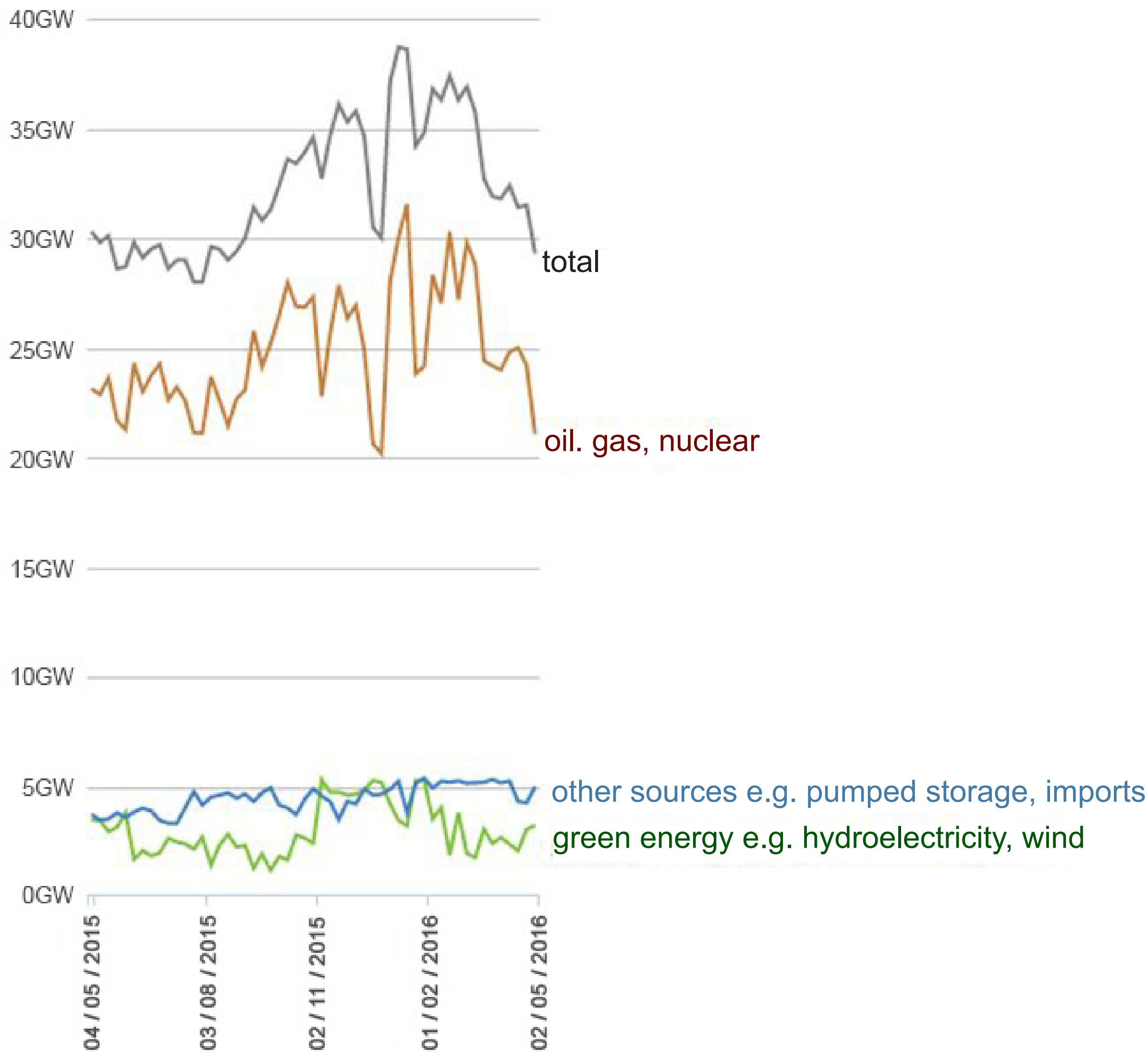
The start-up time and carbon footprint of some different forms of electricity are shown below:

type of power station	nuclear	coal-fire	oil-fire	gas turbine	pumped storage
start-up time	48 h	6 h	12 h	2 min	10 s

The National Grid uses different sources of energy in order to ensure that there is an uninterrupted supply of electricity. The UK also has agreements with some other countries which allows for the import or export of electricity when necessary. For example, a 2 GW bidirectional cable links the UK National Grid to that in France. A similar 1 GW cable connects the UK Grid to that in the Netherlands.

The graph below shows how the energy sources used to generate electricity in the UK varied over a one year period:

Energy sources used between May 2015 - May 2016



GENERATING ELECTRICITY AT HOME

If you want to make a difference and generate electricity, can you make it pay? Payback time can help you decide.

> The payback time of an energy-saving solution is a measure of how cost-effective it is.

For example, if we install solar panels, how long will it take to produce enough energy to pay for the panels?

Payback time can be calculated using:

payback time (days) = cost of installation (£) ÷ savings in fuel costs (per day)(£)

Example

The typical cost of solar panels for a home is £6 000. It is claimed that the panels will produce a saving of £1.20 per day.

Calculate the payback time, in years, of buying the solar panels.

Answer

payback time = 6 000/1.20 = 5 000 days

In a year there are 365 days.

payback time = 5 000/365 = 13.7 years.

Solar panels
Steve Allen Travel Photography / Alamy Stock Photo

TEST YOURSELF

1. Electricity is transmitted at high voltage to:

   A make it safer
   B reduce energy losses
   C increase power

2. Select the correct answer:
   Household voltage is about (**23 V / 230 V / 2300 V / 23000 V**)

3. Look at the table of start-up times for different types of electrical power.
   State which power source can be used to respond most rapidly to an increased demand in electrical power.

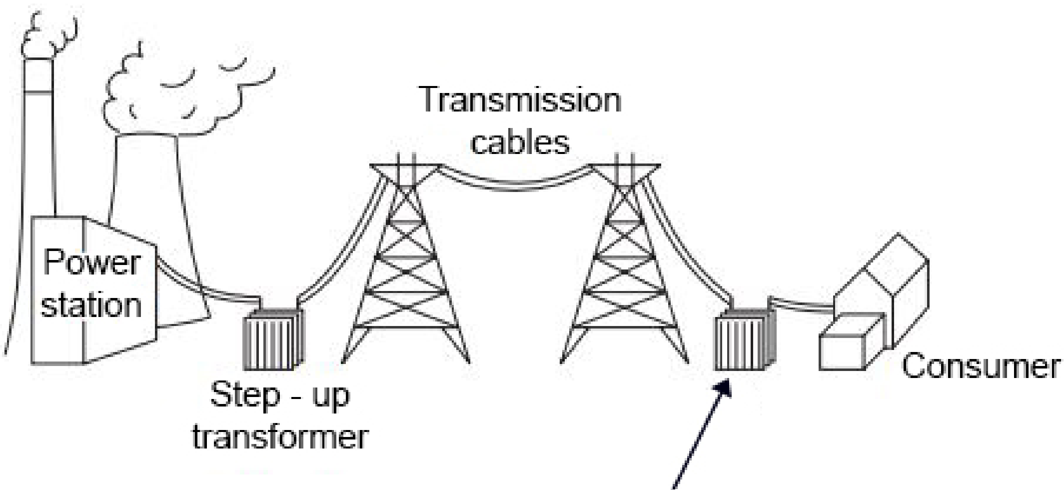
   A nuclear
   B pumped storage
   C coal fire

Modern living and energy (Unit 1.1)

Generating electricity (specification 1.1.2)

PRACTICE QUESTIONS

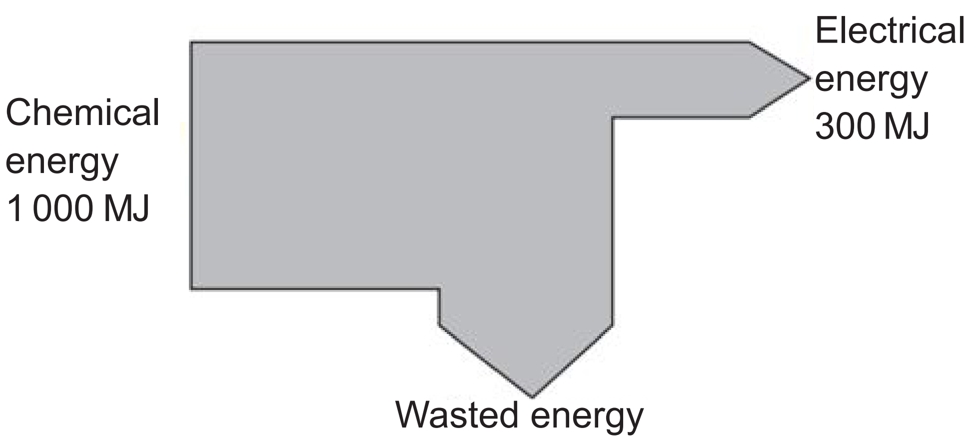
1. The diagram shows how electricity is distributed from a power station to consumers.



....

(a) Fill in the missing label on the diagram. **[1]**

(b) The Sankey diagram shows the energy transfers for this power station.



(i) How much energy is wasted? .... MJ **[1]**

(ii) What happens to this wasted energy? **[1]**

……………………………………………………………………………………..

(iii) Calculate the efficiency of the power station using **[2]**

$$\%\ \text{efficiency} = \frac{\text{energy usefully transferred}}{\text{total energy supplied}} \times 100$$

% efficiency = ………………………..

2. Some of the power stations that supply energy to the National Grid system are nearing the end of their useful life.

(a) Explain why a National Grid system is necessary. **[2]**

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

(b) A planning department is considering proposals for two different types of electrical power generation.

Compare the advantages and disadvantages of generating electricity using wind and nuclear power.

[6 QER]

....

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....

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....

....

(c) Health and Safety Officers ensure people are protected from the dangers of the high voltages being distributed from transformers.

Use the equation:

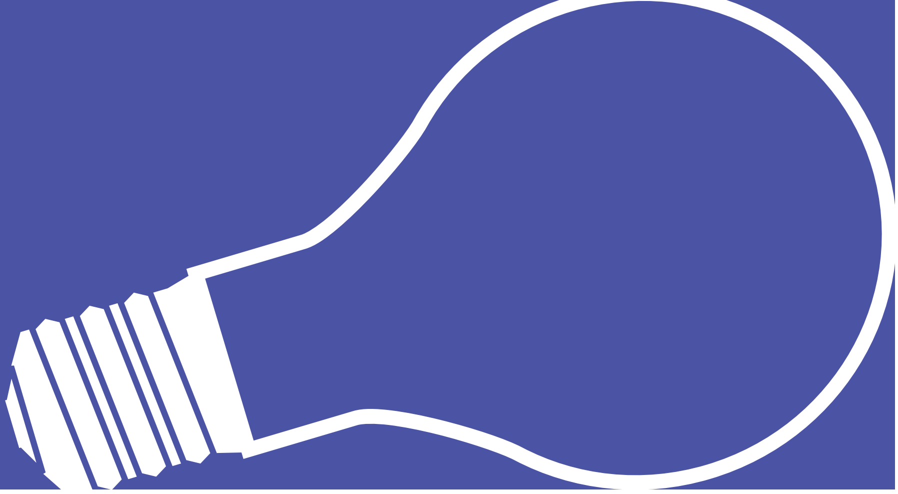
power = voltage × current

to calculate the voltage if a transformer distributes electricity at a power of 90 MW (90 × 106 W) and at a current of 60 A. **[3]**

voltage = ...

Modern living and energy (Unit 1.1)

Making use of energy (specification 1.1.3)



Modern living and energy (Unit 1.1)

Making use of energy (specification 1.1.3)

REDUCING OUR ENERGY DEMANDS

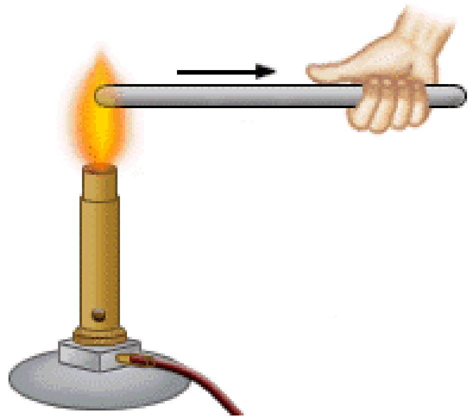
Energy is an expensive commodity and it is important that we do not waste it, either in the home or industry. The production of energy also leads to the formation of greenhouse gases so the more efficiently we use energy, the lower our carbon footprint will be and the smaller our impact on the environment.

Energy transfers

There are three ways that energy can be transferred: conduction, convection and radiation.

Conduction

Heat is transferred from one part of a **solid** to another **without** particles moving through the material.



Heat conducted through a metal rod
Unable to trace copyright.
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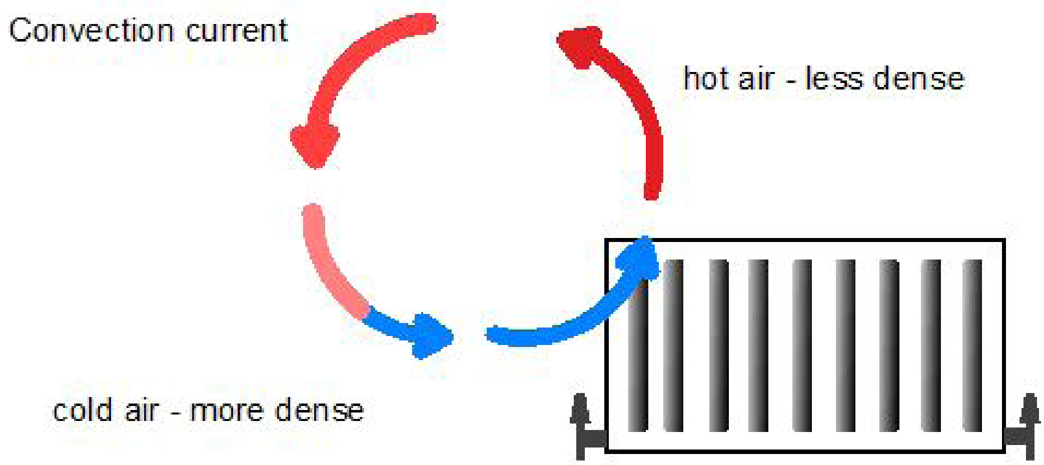
Convection

Heat is transferred through a **gas** or **liquid** by the particles which can move.
The movement occurs because hot gases and liquids are less dense than cold. This causes convection currents to occur transferring the heat energy.



Radiation

Radiation is the transfer of heat energy by electromagnetic waves. It does not involve the movement of matter and is able to move through a vacuum.

All objects give out and take in thermal radiation (infrared radiation). The hotter an object is, the more infrared radiation it emits.

Infrared radiation:

- can be reflected by shiny surface
- is absorbed best by black, dull surfaces but **not** shiny surfaces.

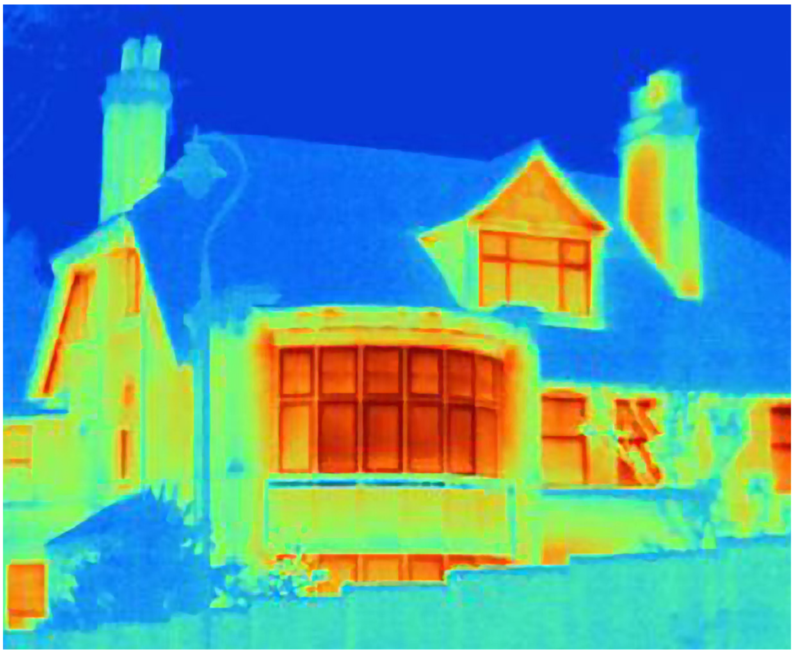
Sand dunes
Nino Marcutti / Alamy Stock Photo

Radiation can travel to us through of space.

Insulating homes

When we insulate our homes we reduce the heat loss, use less fuel and save money. Energy is loss from a house through:

- the roof
- windows
- gaps around the door
- the walls
- the floor.



Thermal house
Cultura RM / Alamy Stock Photo

Thermal image of a house showing most energy is lost from the windows

Heat energy is lost from our homes by:

- conduction through the walls, floor, roof and windows
- convection e.g. cold air can enter the house through gaps in doors and windows
- radiation through the walls, roof and windows.

Ways to reduce heat loss

In order to prevent the loss of heat energy we can fit insulation. Still air is a good insulator so materials with air trapped in them are good insulators.

Some simple ways to reduce heat loss include:

- having cavity walls. The air gap between the walls stops heat loss by conduction
- using cavity wall insulation to further reduce heat loss through the walls. This involves blowing insulating material into the gap between the brick and the inside wall. The material prevents air circulating inside the cavity, therefore reducing heat loss by convection
- laying loft insulation to reduce heat loss through the roof. This works in a similar way to cavity wall insulation
- putting reflective foil on the walls to reflect radiation
- fitting double glazing to reduce heat loss from window

There may be air (or a vacuum) between the two panes of glass. Air is a poor conductor of heat, whilst a vacuum can only transfer heat energy by radiation.

New windows
Paul Glendell / Alamy Stock Photo

All these improvements cost money to buy and install, but they save money on fuel costs. The time it takes to save the cost of buying and fitting the insulation is called the 'payback time'. It can be calculated using:

$$\text{payback time} = \frac{\text{insulation cost}}{\text{annual savings}}$$

Example

It costs £2 400 to fit double glazing in a house. The annual energy savings are £200 per year.

Calculate the payback time.

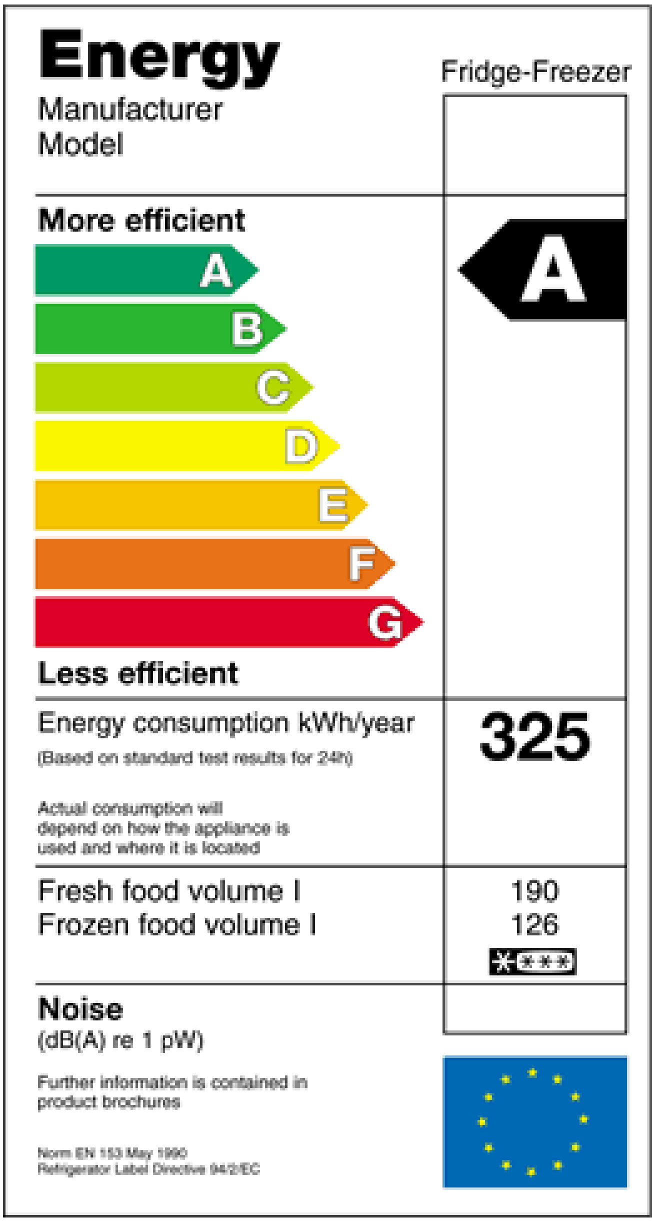
Answer

$$\text{payback time} = \frac{\text{insulation cost}}{\text{annual savings}}$$

$$\text{payback time} = \frac{2\,400}{200} = 12 \text{ years}$$

Saving energy by choosing wisely

Electrical appliances use energy. When we buy electrical appliances we can use the energy banding label of appliances to choose the most efficient.



This is a label designed for all countries in the EU and must be shown by UK law. It shows a lot of information for the appliance.

Examples of appliances you will find energy labels on include:

- refrigerators
- freezers
- washing machines
- tumble dryers
- electric ovens
- lamps

Appliances are rated A to G. An A rated appliance uses about half the energy of a G rated appliance.

An energy consumption figure is given with each appliance which is an estimate of how much electricity it will use each year.

Modern living and energy (Unit 1.1)

Making use of energy (specification 1.1.3)

Energy efficient bulb

We can compare power use using the **power rating**. The two lamps (light bulbs) below produce about the same amount of light but the LED lamp uses about 10% of the power of the traditional incandescent lamp. LED lamps are also expected to last 25 times as long.

Incandescent lamp
Nattakit / gettyimages

LED lamp
LED bulb. Wikimedia Creative Commons
http://bit.ly/2dqnQQZ

A 40 W incandescent lamp	4.5 W LED
£1.66	£3.86
average life approx. 1 000 hours	average life approx. 25 000 hours

Calculate the cost of the incandescent lamp and LED lamp for one year (assume about 1 000 hours of use). Cost of one unit = 8.0 pence

units used = power (kWh) × time (h)
total cost = cost of one unit × units used

Answer

Incandescent lamp

units used = 0.04 × 1 000
= 40 (kWh)

cost = 40 × 0.08 = £3.20

LED

units used = 0.0045 × 1 000
= 4.5 (kWh)

cost = 4.5 × 0.08 = £0.36

Energy savings and car engines

How do different types of car engines compare? Does one type stand out as more energy efficient than the others? The answer is yes! Consider the following information:

- Modern **petrol engines** have a **maximum** thermal efficiency of about 25% to 30% when used to power a car. This is a figure that a car engine **cannot ever** exceed. In other words only **25-30%** of the energy available can be used to move the car even when it is operating to its maximum efficiency. The rest is lost as heat energy.

- **Diesel engines** are better with a maximum thermal efficiency of about 40%.

- **Electric cars** have motors and not engines. In this case, the motor can use about **80-94%** of the energy efficiently.

- This also means that electric motors also have the lowest carbon footprint to drive even when you take into account the fossil fuels required to generate electricity.

Efficiency: Electric motors >> diesel engine > petrol engine

The figures quoted above are maximum figures. In reality the performance is poor. Probably only 15% of the energy available in petrol actually goes into moving the car.

Some examples of how energy is lost include:

Idling

In city driving a lot of energy is lost to idling at red lights or in slow moving traffic. 'Eco' systems help reduce these losses by automatically turning off the engine when the vehicle comes to a stop and restarting it instantaneously when the accelerator is pressed.

Overcoming inertia

To move a vehicle forward enough energy must be provided to overcome the vehicle's inertia. The less a vehicle weighs the less energy it takes to move it.

Weight can be reduced by using lightweight materials.

Rolling resistance

Rolling resistance is a measure of the force necessary to move the tyre forward. It is directly proportional to the weight of the load supported by the tyre.

New technologies including improved tyre tread and materials used in the tyre, can be used to reduce rolling resistance.

Accessories

Air conditioning, power steering, windshield wipers, and other accessories use energy generated from the engine. Fuel economy improvements of up to 1 percent may be achievable with more efficient alternator systems and power steering pumps.

Aerodynamic drag

A vehicle must use energy to move air out of the way as it goes down the road. Drag is directly related to the shape of the vehicle.

Better vehicle shapes have reduced drag significantly, but further reductions of 20 - 30% are possible.

Modern living and energy (Unit 1.1)

Making use of energy (specification 1.1.3)

TEST YOURSELF

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1. Heat travels through the base of a saucepan. This is an example of:

A radiation
B convection
C conduction

2. Thermal energy can be carried through a vacuum by:

A radiation
B convection
C conduction

3. Infrared radiation is:

A better absorbed by dark dull surfaces than shiny surfaces
B better absorbed by shiny light surfaces than dark dull surfaces
C absorbed by about the same amounts by shiny light surfaces and dark dull surfaces

4. Trapped air is a:

A poor insulator of heat
B good conductor of heat
C good insulator of heat

5. An electrical appliance has an energy consumption of 500 kWh/year.
The cost of one unit of electricity is 10 pence. The total running cost each year is:

A £5 000
B £500
C £50

6. The following design change can improve the fuel efficiency of a car

A use stronger components which weigh more
B improve the aerodynamic shape of the car
C use air conditioning frequently to reduce thermal losses

7. We can reduce our carbon footprint by using cars powered by:

A petrol engines
B diesel engines
C electric motors

PRACTICE QUESTIONS

1. Homeowners can no longer buy 100 watt filament lamps. As an alternative they can replace them with compact fluorescent lamps (CFL)

The table below shows some data about two types of lamps that give out the same amount of light.

	Filament lamp	CFL
power (kW)	0.1	0.02
power (W)	100	20
efficienc	2.5%	12%
cost	50 p	£2.50
lifetime (hours)	1 000	12 000

(a) Efficiency is calculated using the equation:

$$\text{efficiency} = \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100$$

(i) Explain what is meant by the statement 'The efficiency of a filament lamp is 2.5%' **[2]**

....

....

PRACTICE QUESTIONS

(ii) Calculate the difference in useful energy transfer between the two types of lamps if both have a total energy input of 1 000 J. **[2]**

Difference in useful energy transfer = ……………J

(b) Use the equations below to answer the questions that follow.

units used = power (kW) × time (h)
cost = units used × cost per unit

(i) Calculate the number of units of electricity used by a CFL in its lifetime. **[2]**

Number of units used = …………… kWh

(ii) How many units of energy would the equivalent filament lamp use in 12000 hours? **[1]**

(iii) Calculate the money saved on using electricity over 12 000 hours by changing to a CFL. **[3]**

One unit of electricity costs 12 p.

Money saved = ……………………..

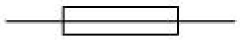
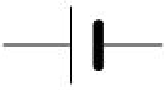
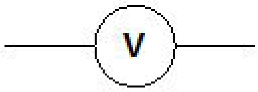
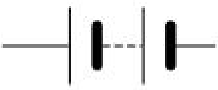
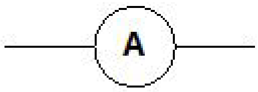
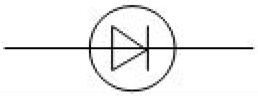
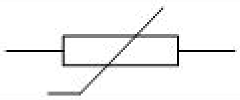
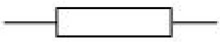
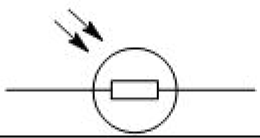
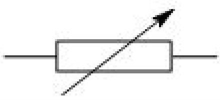
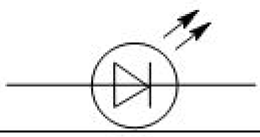
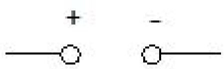
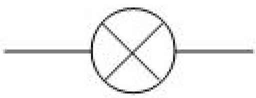
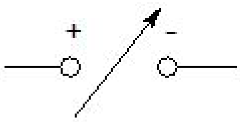
Modern living and energy (Unit 1.1)

Building electric circuits (specification 1.1.4)

INTRODUCING ELECTRICAL CIRCUITS

We use electrical devices in our homes, work places and for leisure. In order to understand their use, it is important to understand how electrical circuits work. Electric circuits are designed for their purpose. Circuits can be represented in a circuit diagram by making use of symbols. You need to be aware of the circuit symbols for this topic.

Circuit Symbols

Component	Symbol	Component	Symbol
	switch		fuse
	cell		voltmeter
	battery		ammeter
	diode		thermistor
	resistor		LDR
	variable resistor		ac power supply
	LED		dc power supply
	lamp		variable dc power supply

Modern living and energy (Unit 1.1)

Building electric circuits (specification 1.1.4)

Making a circuit

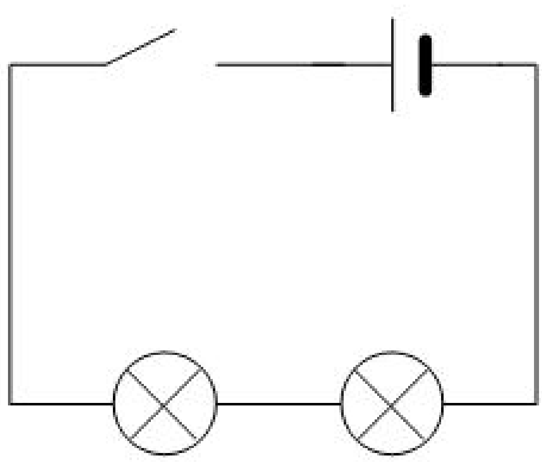
An electric current is a flow of electrical charge. The charge only flows if there is a complete circuit.

Series circuits

A series circuit is one with **one** route around it.

In a series circuit:

- the current is the same through the circuit
- the total voltage is the sum of the voltages across each component



A series circuit

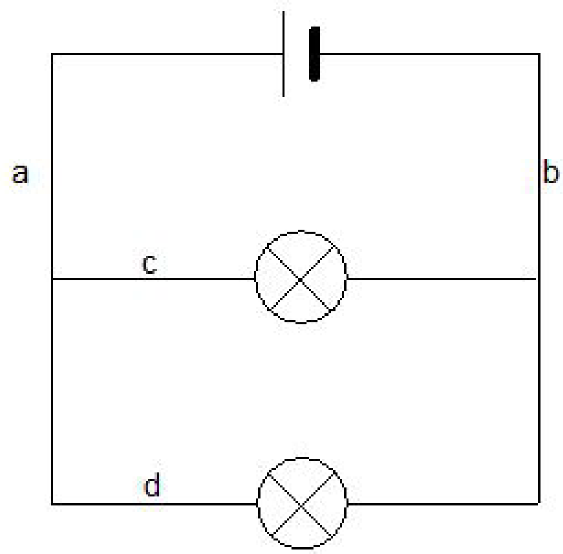
If either lamp in the circuit above breaks then this breaks the circuit and no current will be able to pass through the second lamp.

Parallel circuits

A parallel circuit is one with one with more than one route around it.

In a parallel circuit, the total current before it splits at a junction equals the sum of the currents in the branches.

In the circuit below, the **current at point a = current at b = the sum of the currents at c and d.**



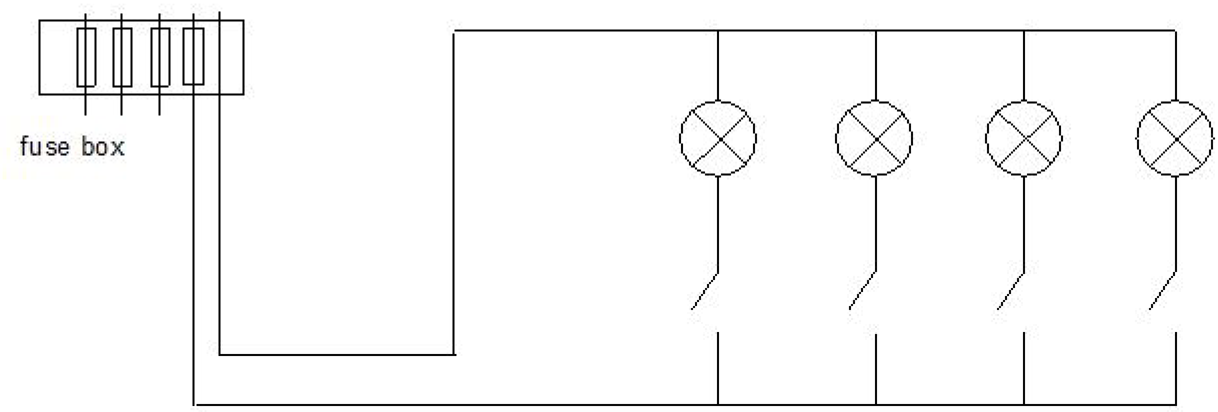
The **voltage across each component in parallel is the same.**

Electrical circuits in the home

Most of the mains circuits in your home are connected in parallel. This has several advantages:

- the voltage is the same for all components
- if one component stops working this will not stop the current flowing to the othe components; they will continue to work
- it is safer since each component will be protected by its own fuse.

A circuit diagram for a household mains lighting circuit showing four lamps in parallel is drawn below. If one lamp breaks the other components will continue to work. There is the same voltage drop across each component. A fuse box or circuit breaker will protect the circuit.



Using ammeters and voltmeters

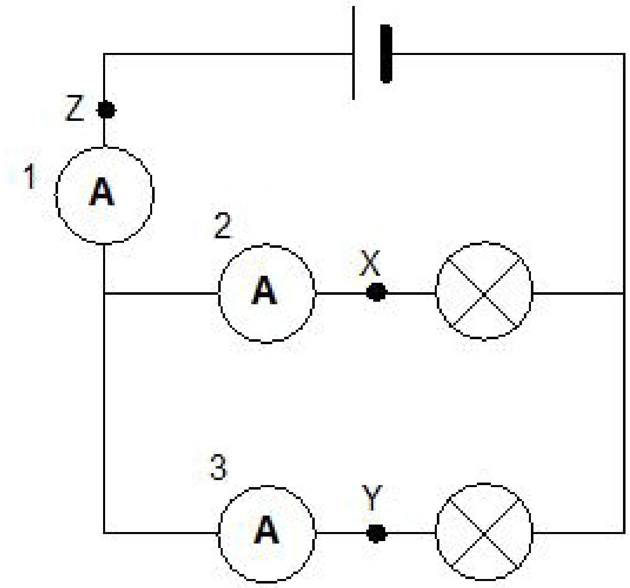
Electrical **current** is measured in amperes (amps), A.

Ammeters are used to measure the electrical current **through** a component.
Ammeters must be connected in series with the components.

Modern living and energy (Unit 1.1)

Building electric circuits (specification 1.1.4)

In the diagram, ammeter 1 measures the current Z, ammeter 2 measures the current X and ammeter 3 measures the current Y.



Voltage, also called potential difference, is measured in volts, V, using a voltmeter.

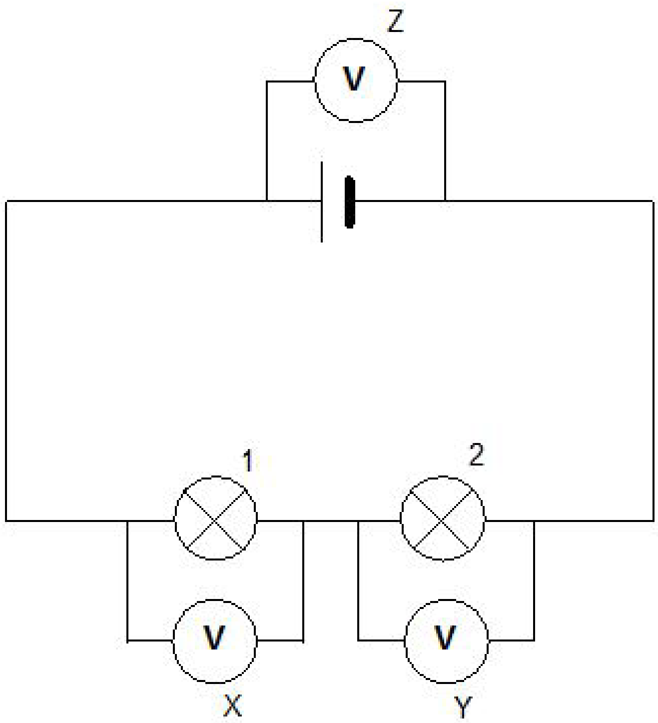
Voltmeters must be connected **in parallel** to the component.

A voltmeter measures the voltage **across** a component.

The higher the voltage of a battery, the greater the 'push' on the charges in the circuit.

In the circuit diagram below:

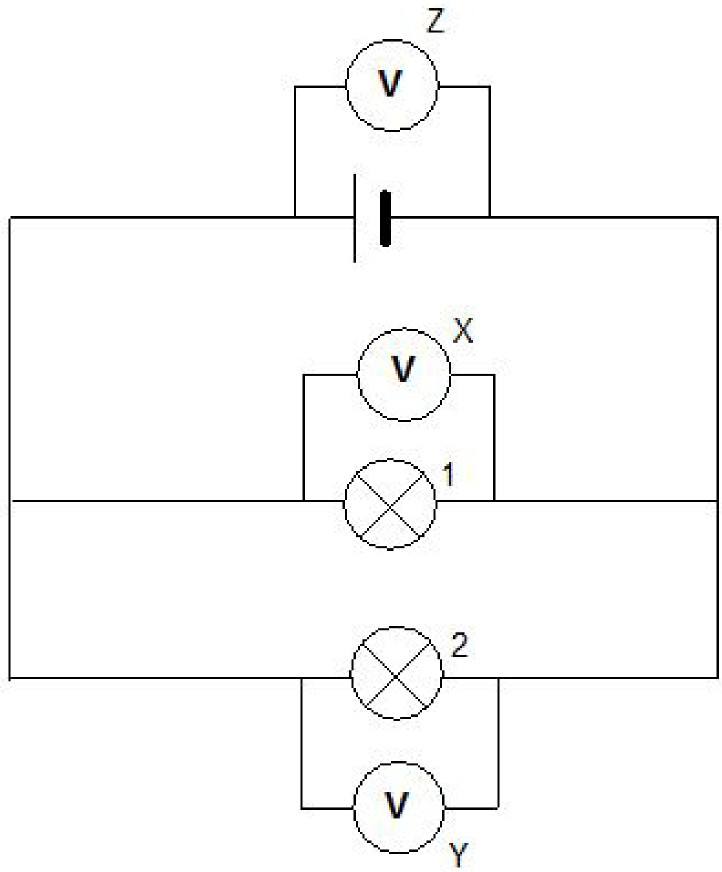
- voltmeter **X** is placed in parallel with lamp 1. It measures the voltage drop (V_1) across lamp 1.
- voltmeter **Y** is placed in parallel with lamp 2. It measures the voltage drop (V_2) across lamp 2.
- voltmeter **Z** measures the total voltage (V_T) supplied by the cell.
- In this series circuit, $V_T = V_1 + V_2$.



In the parallel circuit diagram below, the total voltage supplied by the battery (V_T) is the **same** as the voltage across:

- lamp 1 (V_x measured by voltmeter X)
- lamp 2 (V_y measured by voltmeter Y)

i.e. $V_T = V_x = V_y$



Resistance

The components in an electrical circuit resist the flow of the electrical charge. Resistance to the flow of the electrical current is measured in ohms (Ω). We can find it from the voltage and current.

$$\text{resistance} = \frac{\text{voltage}}{\text{current}} \qquad R = \frac{V}{I}$$

The **larger the resistance** (R) in a circuit, **the smaller the current** (I) flowing (assuming that the voltage (V) is fixed). If voltage is constant then:

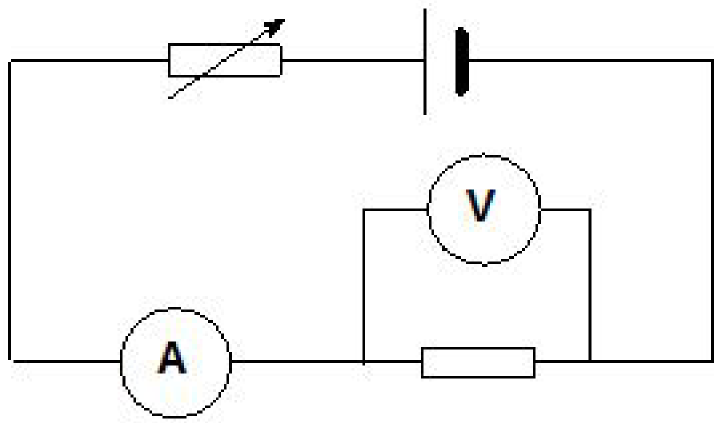
$$I \propto \frac{1}{R}$$

If the resistance is constant then $I \propto V$

Investigating current changes with voltage

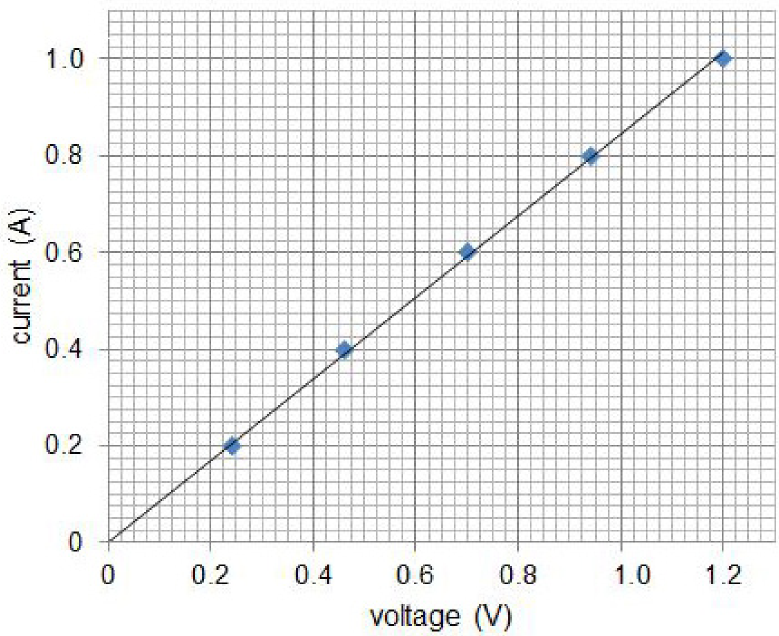
The resistance of connecting wires can be assumed to be so small that it can be ignored.

The following circuit diagram can be used to investigate how current varies with voltage for a resistor.



The variable resistor is used to control the current through and voltage across a fixed resistor. The temperature is kept the same for all the measurements.

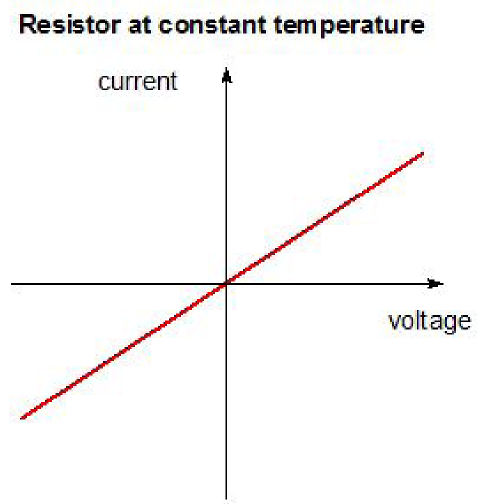
Typical graph of results



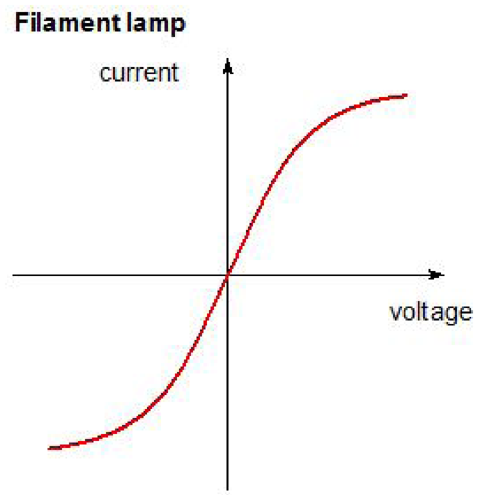
You can also use this circuit to investigate other types of components by swapping the fixed resistor for, e.g. a filament lamp or a diode.

You need to be familiar with the results that you observe with a:

- resistor at constant temperature
- filament lamp
- diode.

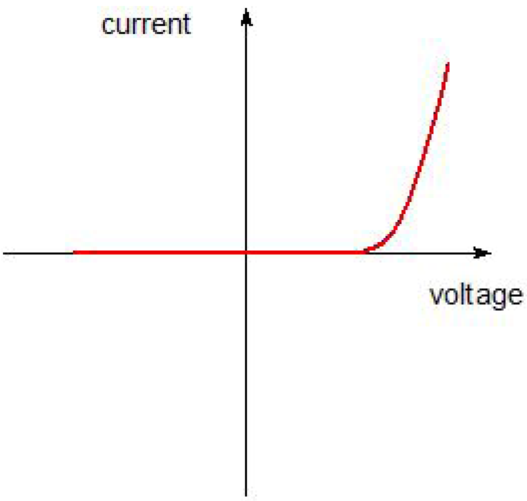


A resistor (at constant temperature) will always give a straight line; the current and voltage are directly proportional to each other. In other words, the resistance of the resistor stays constant.



The **resistance changes** with **current** so you do not have a straight line graph.

The resistance of the lamp increases with current.



A diode has a very high resistance in one direction. This means current can only flow in one direction.

Modern living and energy (Unit 1.1)

Building electric circuits (specification 1.1.4)

Combining resistors

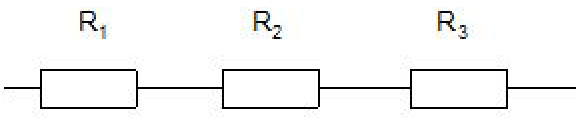
When we add components to a circuit we change the resistance of a circuit.

If we add the components in:

- **series** then we **in**crease the total resistance of a circuit
- **parallel** then we **de**crease the total resistance in a circuit.

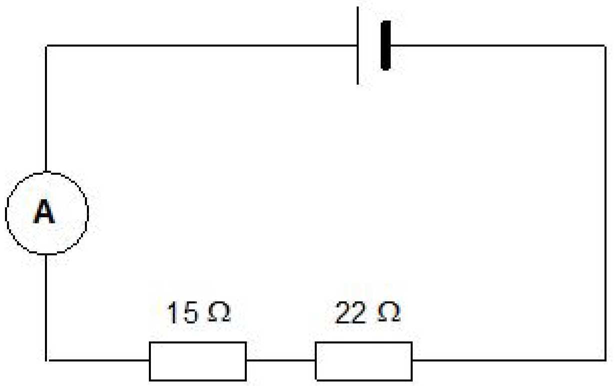
Adding resistors in series

The current will pass through each of the components that are in series.
The total resistance (R_T) = the sum of the separate resistances.
For three resistors in series, R_1, R_2 and R_3

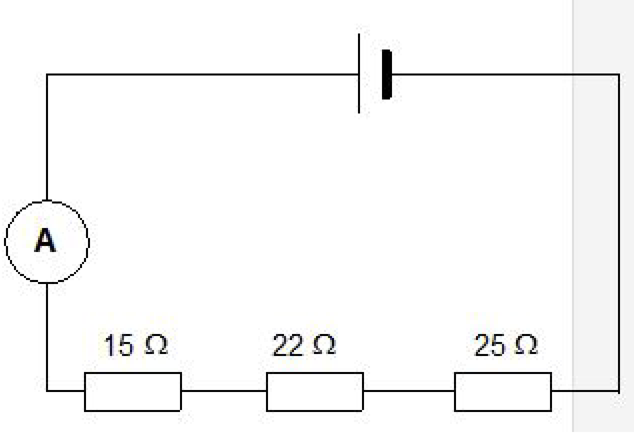


$R_T = R_1 + R_2 + R_3$

Example



Total resistance = 15 + 22 = 37 Ω



Total resistance = 15 + 22 + 25 = 62 Ω

Modern living and energy (Unit 1.1)

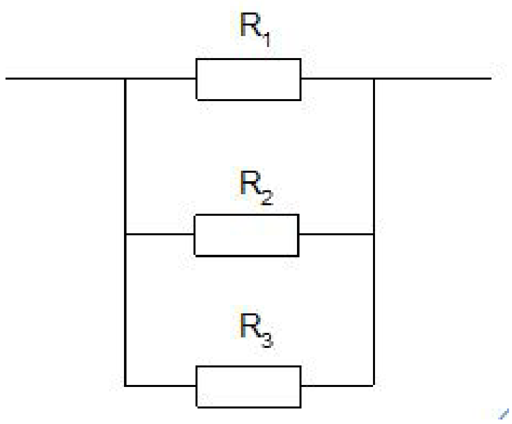
Building electric circuits (specification 1.1.4)

Adding resistors in parallel

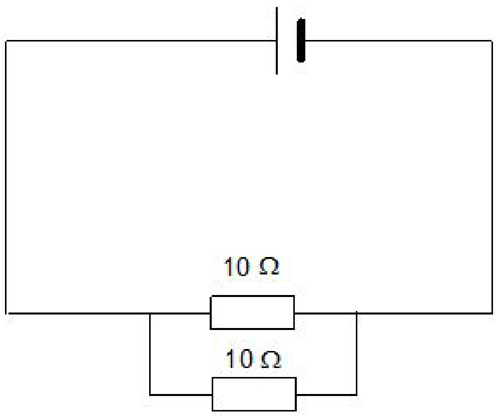
The total resistance falls. The current through each resistor will be the same as if it were the only component but there are now more ways that the current can pass through the circuit. This means the total current is larger.

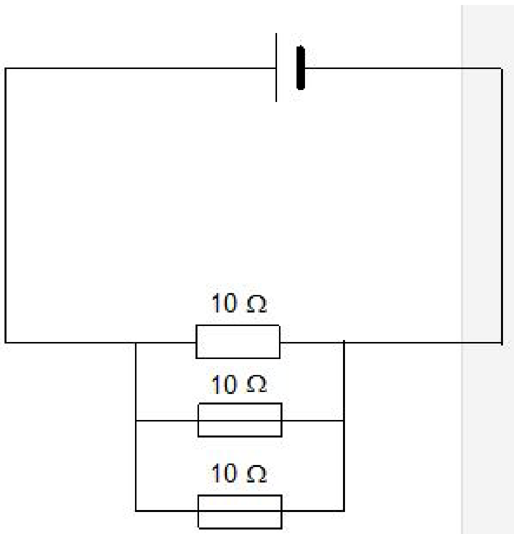
Finding the total resistance is a little more difficult. For three resistors in parallel, the total resistance, R_T can be calculated using:

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3$$



Example





1/RT = 1/10 + 1/10
1/RT = 2/10
RT = 10/2 = 5 Ω

1/RT = 1/10 + 1/10 + 1/10
1/RT = 3/10
RT = 10/3 = 3⅓ Ω

Finding current, voltage and power in electrical circuits

We have already seen that:

$$I = \frac{V}{R}$$

Power can be calculated using:

power = voltage × current $\boldsymbol{P = I \times R}$

HIGHER TIER ONLY

You need to know: power = current^2 × resistance $P = I^2 \times R$

Examples

1. Calculate the resistance of a filament lamp operating at 6 V with a total current of 0.5 A through it.

Use: $R = \frac{V}{I}$

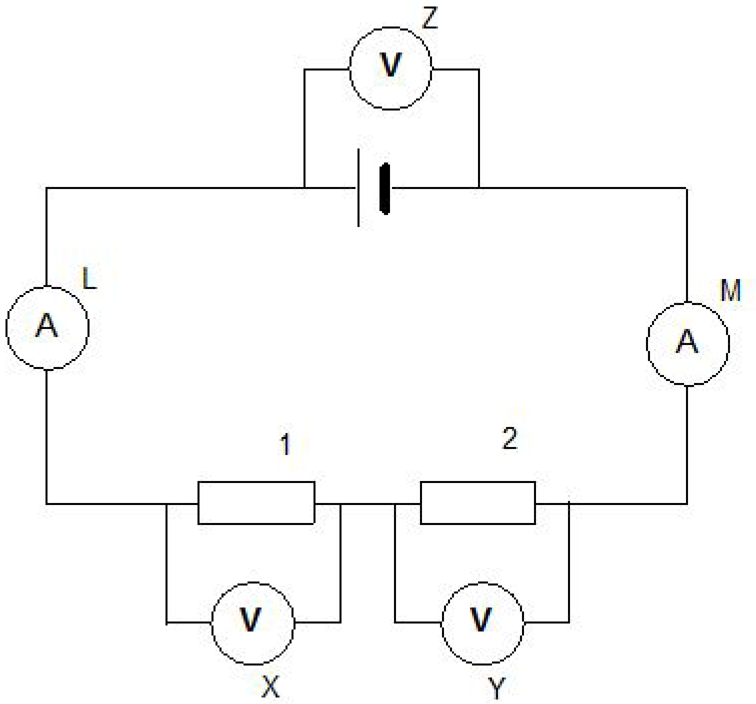
$$R = \frac{6}{0.5} = 112\ \Omega$$

2. Calculate the power of a filament lamp operating at a voltage of 12 V and a current of 0.3 A.

$P = IV$

$P = 0.3 \times 12 = 3.6$ W

3. In the circuit below the voltmeter Z reads 9 V and voltmeter X reads 6 V.
The reading on ammeter L = 1.5 A.



(a) State the reading on ammeter M and on voltmeter Y.

(b) Calculate the total resistance and the resistance of resistor R_1.

Answer

(a) Ammeter M reading = 1.5 A (current is the same everywhere in a series circuit)
Voltmeter Y reading = 9 – 6 = 3 V
(The total voltage = the sum of the individual voltages across each component)

(b) total resistance = total voltage / current = 9/1.5 = 6 Ω
resistance of R1 = voltage / current = 6/1.5 = 4 Ω

Higher tier only

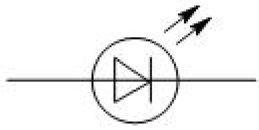
4. A fixed resistor with a resistance of 20 Ω has a current of 0.5 A through it. Calculate the power of the lamp.

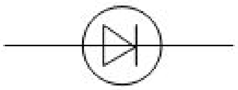
   $P = I^2R$

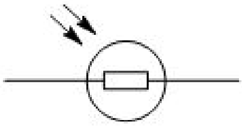
   $P = 0.5^2 \times 20 = 5$ W

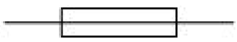
TEST YOURSELF

1. The symbol for a diode is:

A 

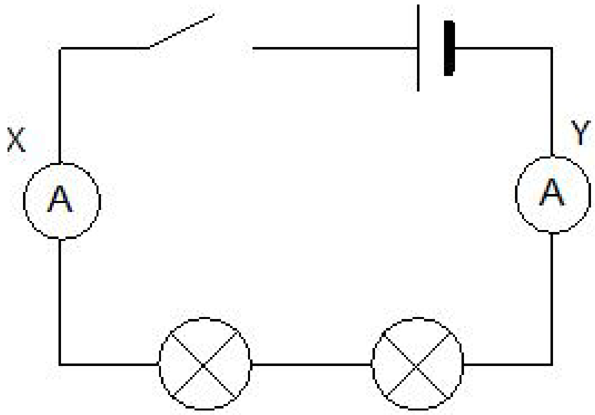
B 

C 

2.  is the symbol for a:

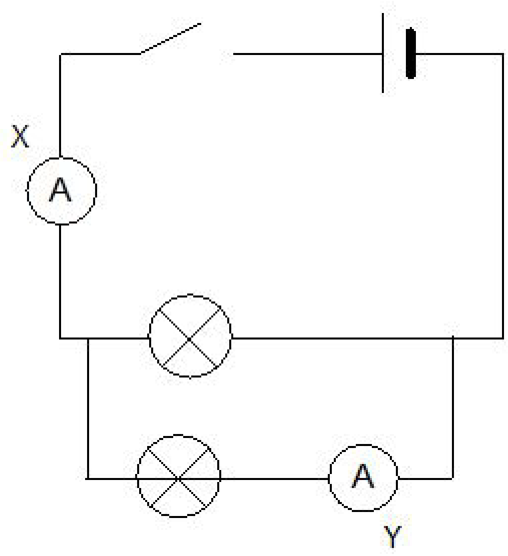
A resistor
B thermistor
C fuse

3. Look at the following circuit. The reading on ammeter Y is:



A the same as the reading on ammeter X
B smaller than the reading on ammeter
C larger than the reading on ammeter X

4. Look at the following circuit. The reading on ammeter Y is:



A the same as the reading on ammeter X

B smaller than the reading on ammeter X

C larger than the reading on ammeter X

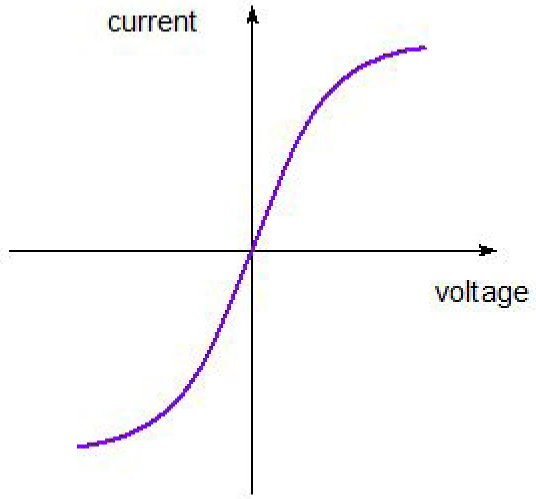
5. When a voltmeter is used to measure the voltage across a component, it must be connected:

A next to the cell

B in parallel to the component

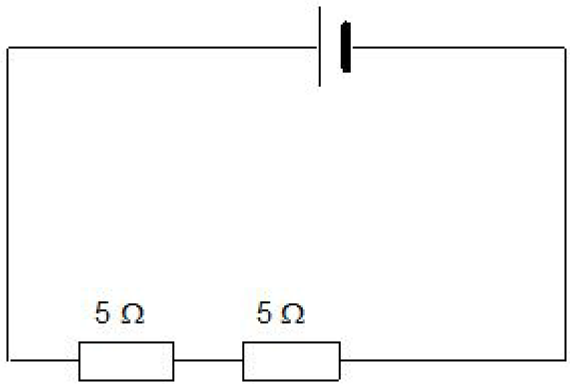
C in series with the component

6. Look at the graph and state what type of component was tested.



A diode
B resistor
C filament lamp

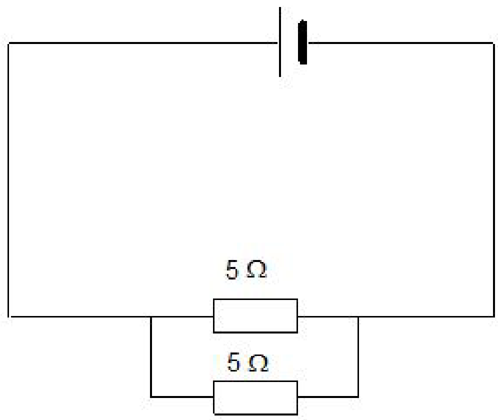
7. Calculate the total resistance for the circuit below.



The total resistance is:

A 10 Ω
B 2.5 Ω
C 5 Ω

8. Calculate the total resistance for the circuit below.



The total resistance is:

A 10 Ω
B 2.5 Ω
C 5 Ω

9. Calculate the resistance through a filament lamp operating at 6 V with a current of 0.6 A through it.

$$R = \frac{V}{I}$$

A 0.10 Ω
B 3.6 Ω
C 10 Ω

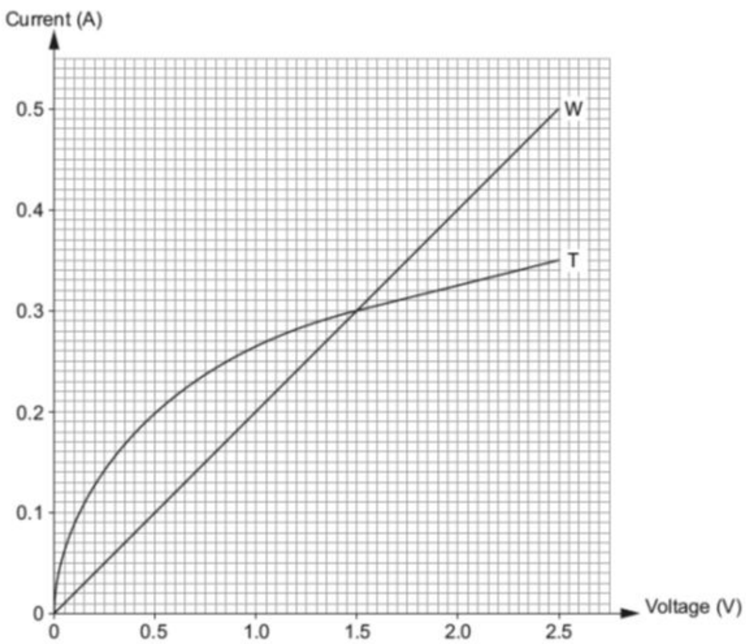
10. Calculate the power of a filament lamp operating at a voltage of 9 V and a current of 0.3 A.

Use $P = IV$

A 0.3 Ω
B 30 Ω
C 2.7 Ω

PRACTICE QUESTIONS

1. The graph shows how the current depends upon the voltage for a torch lamp (T) and a long copper wire (W).



(a) **(i)** Compare how the current in the wire and lamp varies as the voltage increases from 0 to 2.5 V. **[3]**

....

....

....

....

(ii) Use the graph to find the voltage at which the currents in the lamp and wire are the same. **[1]**

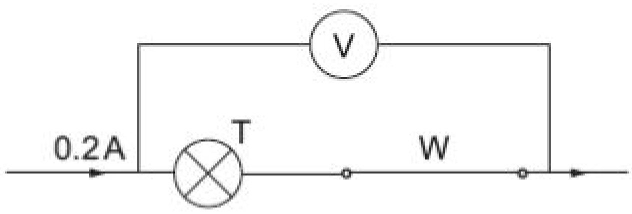
current = …………… A

(iii) Calculate the resistance of the wire at this voltage using the equation: **[3]**

$$\text{resistance} = \frac{\text{voltage}}{\text{current}}$$

resistance = ………………. Ω

(b) The lamp bulb and wire are shown connected in series with a current of 0.2 A flowing through them.



Use the graph to calculate the reading on the voltmeter. **[3]**

voltmeter reading = ………….. V

TEST YOURSELF - ANSWERS FOR UNIT 1.1

Energy and efficienc

1. B

Paying for electricity

1. C
2. A
3. watts, J/s

Carbon footprint

1. B
2. C
3. B

Generating electricity

1. B
2. 230 V
3. B

Reducing our energy demands

1. C
2. A
3. A
4. C
5. C
6. B
7. C

Building electric circuits

1. B
2. C
3. A
4. B
5. B
6. C
7. A
8. B
9. C
10. C

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

ELEMENTS

How can we obtain clean water? To answer this question we need to think about what water is.

Pure water is a compound. It is made of two different elements, hydrogen and oxygen, which are chemically joined together. Hydrogen and oxygen are examples of elements.

Elements are substances that cannot be broken down by chemical means. They are made up of one type of atom. Elements are the building blocks of all substances.

There are 118 known elements but many of these are not stable. Only about 80 elements are stable and are met outside the laboratory. Each element has a name and symbol.

Elements are arranged in a special table called the Periodic Table (see Topic 1.2.2). The Periodic Table gives the name and symbol and other information about the element.

Examples of elements

Symbol	Name	Symbol	Name
H	hydrogen	Li	lithium
O	oxygen	Na	sodium
N	nitrogen	K	potassium
Cl	chlorine	Mg	magnesium
Br	bromine	Ba	barium
C	carbon	Fe	iron
S	sulfur	Cu	copper
P	phosphorus	Zn	zinc

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

1. Select the correct symbol for each of the following:

a hydrogen

A Hy **B** Ho **C** H

b chlorine

A C **B** Ch **C** Cl

c sulfur

A Su **B** S **C** Sr

d potassium

A K **B** P **C** Pt

e sodium

A NA **B** Na **C** N

f copper

A Cu **B** Co **C** C

g zinc

A Zn **B** Z **C** Zi

h lithium

A L **B** Lm **C** Li

2. Identify the element from the symbol in the following:

a The element Fe

A lithium **B** lead **C** iron

b The element P

A potassium **B** phosphorus **C** platinum

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

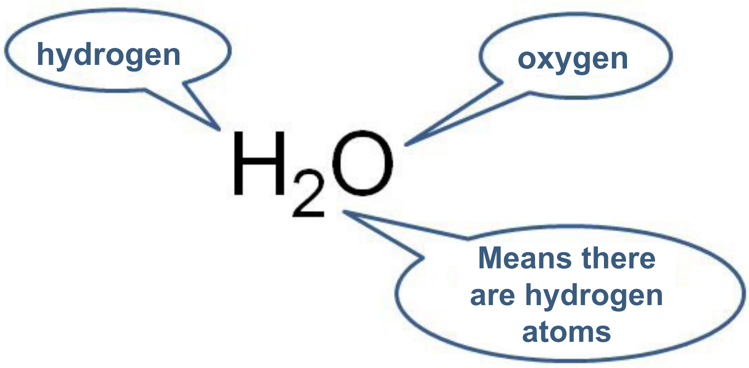
COMPOUNDS

Most chemicals we meet are compounds.

> A **compound** is made of two or more different kinds of atoms.
>
> The different elements are bonded (chemically joined) to each other.

We can use the symbols of chemical elements to write down the formula of compounds. A chemical formula tells us exactly what a compound is made of.

An example: Water



Water has the formula H_2O. This tells us it always contains three atoms; two hydrogen atoms and one oxygen atom. These atoms are chemically joined together. The formula of water is always H_2O. It cannot be changed.

All compounds can be written down using a chemical formula.

Examples of some common compounds

Compound	Formula
carbon dioxide	CO_2
ammonia	NH_3
sodium chloride	NaCl

Brackets in chemical formulae

Some chemical formulae have brackets in them. An example is magnesium hydroxide, $Mg(OH)_2$. The number 2 outside the brackets tells you that you have two of everything in the brackets. There is one magnesium atom, two oxygen atoms and two hydrogen atoms.

Further examples of brackets in formulae

Name	Formula	Iron atoms	Oxygen atoms	Hydrogen atoms	Nitrogen atoms
iron(II) hydroxide	$Fe(OH)_2$	1	1 × 2 = 2	1 × 2 = 2	None
iron(II) nitrate	$Fe(NO_3)_2$	1	3 × 2 = 6	None	1 × 2 = 2

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

Calculate the **total** number of atoms in each of the following:

1 calcium carbonate $CaCO_3$

A 1 B 2 C 3 D 4 E 5

2 barium hydroxide $Ba(OH)_2$

A 1 B 2 C 3 D 4 E 5

3 aluminium nitrate $Al(NO_3)_3$

A 13 B 12 C 11 D 10 E 9

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

ATOMIC STRUCTURE

What is an atom?

What is an atom? What is it made of?

An **atom** is made of a central nucleus surrounded by one or more shells of electrons.

A **nucleus** consists of two kinds of particles; protons and neutrons.

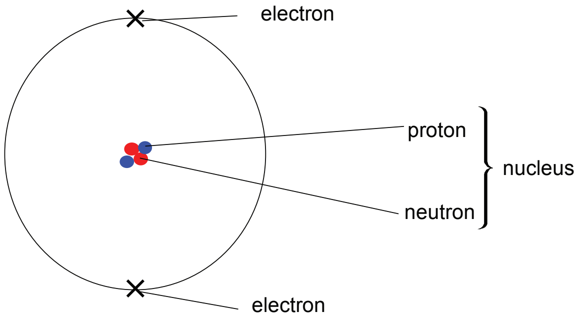
An example: helium

The nucleus of the helium atom has two protons.

There are also two neutrons in this nucleus.

The nucleus of this atom is surrounded by two electrons in one shell.

Each of the particles in an atom has different properties.



Protons have a charge of 1 atomic mass unit (amu) and a charge of +1.
Neutrons have no charge and a mass of 1 amu.
Electrons have a charge of -1 and negligible mass.

An atom will have the **same** number of protons as electrons. It does **not** have an electrical charge.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

Mass number and atomic number

The **mass number** of an atom is the number of protons and the number of neutrons added together.

The **atomic number** is the number of protons in an atom.

The **number of neutrons in an atom = mass number – atomic number**

All the atoms of a particular element **always** have the same number of protons. For example, helium atoms **always** have two protons. We can sum up all the information about helium:

Helium has 2 protons and 2 neutrons. The atom will also have 2 electrons.

mass number → 4
atomic number → 2

$$^{4}_{2}\mathrm{He}$$

Isotopes

The element carbon has an atomic number of 6. It therefore has 6 protons in the nucleus. All atoms that have 6 protons in the nucleus are carbon atoms.

The most common form of carbon has a mass number of 12. It has 12 - 6 = 6 neutrons in the nucleus.

There is another kind of carbon atom. To be carbon it must have 6 protons in the nucleus. However it has 8 neutrons in the nucleus.

The mass number = number of protons + number of neutrons = 8+ 6 = 14

We can summarise the information about these two types of carbon atom:

$$^{12}_{6}\mathrm{C} \qquad ^{14}_{6}\mathrm{C}$$

Isotopes of an element have the same number of protons but a different number of neutrons.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

Try to complete the following table about different isotopes. The first row has been done for you.

Symbol	Mass number	Atomic number	Number of protons	Number of neutrons	Number of electrons
$^{13}_{6}C$	**13**	**6**	**6**	**7**	**6**
$^{35}_{17}Cl$					
	24		12		
		7		7	

ELECTRONIC STRUCTURE

The electrons in an atom are at different energy levels. These energy levels are called **shells.**

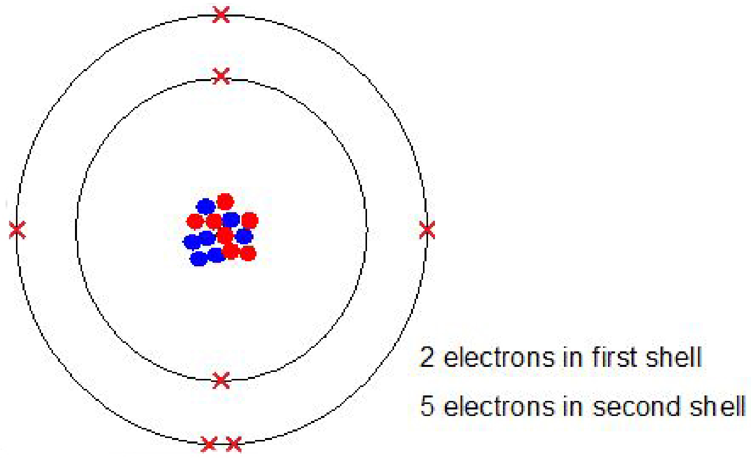
Each shell can contain a maximum number of electrons:

- the first (inner) shell can contain a maximum of two electrons.
- the second and third shell can contain a maximum of eight electrons.

Electronic structure of nitrogen

Nitrogen has an atomic number of 7.

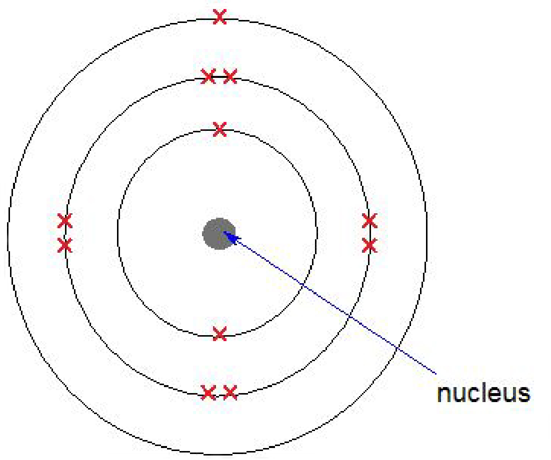
This means it contains 7 protons in the nucleus and 7 electrons in the shells around the nucleus.



The inner shell fills first. This will have 2 electrons. There will be 5 electrons in the second shell.
The electronic structure (electronic configuration) of nitrogen is also written **2,5.**

A comma separates the two shells.

Electronic structure of sodium



The electronic structure of sodium can also be written **2,8,1**.

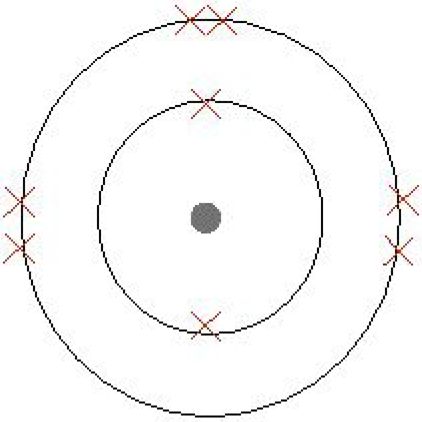
Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

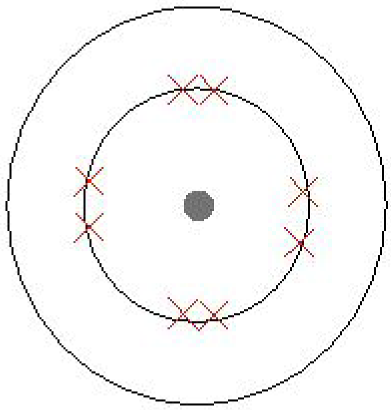
TEST YOURSELF

1. The electronic configuration of oxygen (atomic number 8) is:

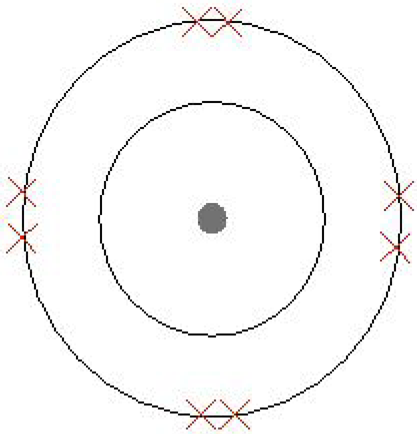
A



B

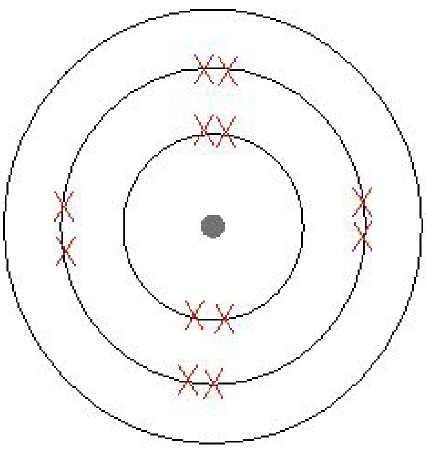


C

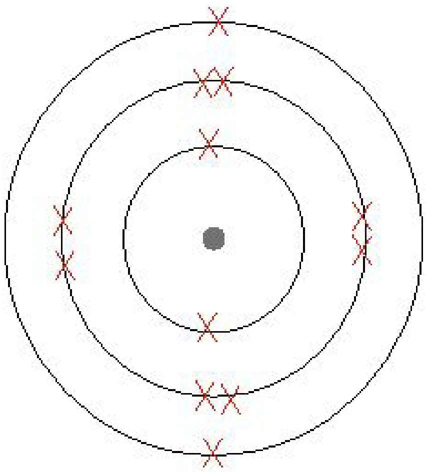


2. The electronic configuration of magnesium (atomic number 12) is:

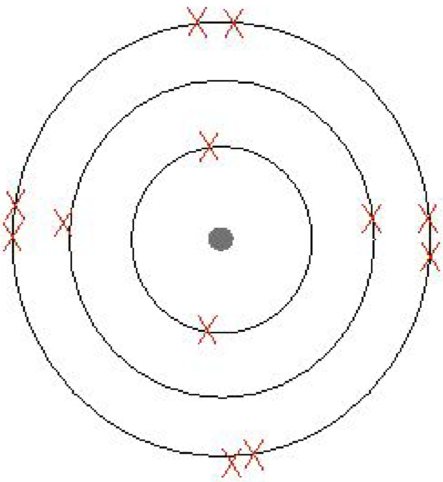
A



B



C



TEST YOURSELF - CONTINUED

3. The electronic structure of chlorine (atomic number 17) is:

A 7,8,2 **B** 2,8,7 **C** 8,7,2

4. The electronic structure of potassium (atomic number 19) is

A 8,8,3 **B** 1,8,8,2 **C** 2,8,8,1

Ions and atoms

Some compounds contain ions. An ion is either positively or negatively charged.
An ion can be formed when:

- a **metal** atom **loses** electrons from its outer shell to form a **positive** ion
- a **non-metal** atom **gains** electrons in its outer shell to form a **negative** ion.

Examples - metals

Na has one electron in its outer shell. If it loses this electron it will have an overall +1 charge.
K has one electron in its outer shell. If it loses this electron it will have an overall +1 charge.

Na	electronic configuration = 2,8,1	Na^{+}	electronic configuration = 2,8
K	electronic configuration = 2,8,8,1	K^{+}	electronic configuration = 2,8,8

Examples – non-metals

F has seven electrons in its outer shell. If it gains one electron it will have an overall -1 charge.
Cl has seven electrons in its outer shell. If it gains one electron it will also have an overall -1 charge.

F	electronic configuration = 2,7	F^{-}	electronic configuration = 2,8
Cl	electronic configuration = 2,8,7	Cl^{-}	electronic configuration = 2,8,8

TEST YOURSELF

1 A negative ion is formed when an atom:

A gains protons **B** gains neutrons **C** gains electrons

2 A positive ion is formed when an atom:

A loses electrons **B** gains protons **C** loses protons

3 When metals form ions, the ion will always be a:

A positive ion **B** negative ion **C** neutral ion

4 A non-metal can gain electrons to form a:

A positive ion **B** negative ion **C** neutral ion

5 The electronic configuration of magnesium is 2,8,2. It forms Mg^{2+} ions. The electronic structure of Mg^{2+} is:

A 8,2 **B** 2,8,4 **C** 2,8

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

WORKING OUT THE FORMULA OF SIMPLE COMPOUNDS

We can use the charge of ions to work out the formulae of compounds made of ions.

We must make sure that the ion charges balance each other out. Compounds will not have a charge.

Examples

Sodium chloride

Ions: Na^{+} Cl^{-}

The ions have the same charge. We will need one of each.

The formula is NaCl.

Sodium oxide

Ions: Na^{+} O^{2-}

Charges on ions: +1 -2

We need **two** $\mathbf{Na^{+}}$ ions for every **one** $\mathbf{O^{2-}}$ to balance the charge.

The formula is Na_2O.

Aluminium bromide

Ions: Al^{3+} Br^{-}

Charges on ions: +3 -1

We need **one** $\mathbf{Al^{3+}}$ ion for every **three** $\mathbf{Br^{-}}$ to balance the charge.

The formula is $AlBr_3$.

You also need to know the formulae of some common ions:

hydroxide OH^{-}
carbonate CO_3^{2-}
sulfate SO_4^{2-}
nitrate NO_3^{-}

Some more examples of formulae

Sodium carbonate

Ions: Na^+ CO_3^{2-}

Charges on ions: +1 -2

We need **two Na^+** ions for every one **CO_3^{2-}** ion to balance the charge.

The formula is Na_2CO_3.

Magnesium nitrate

Ions: Mg^{2+} NO_3^-

Charges on ions: +2 -1

We need **one Mg^{2+}** ion for every **two NO_3^-** ions to balance the charge

The formula is **$Mg(NO_3)_2$**.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

1. Sea water contains large amounts of dissolved ions.
Some of the ions present in sea water are shown in the table below.
Complete the blank spaces in the table.

Metal ion name	Charge on metal ion	Formula of ion	Negative ion name	Charge on negative ion	Formula of ion
sodium		Na^+	bromide	-1	Br^-
	+2	Ca^{2+}		-1	Cl^-
magnesium	+2		sulfate		SO_4^{2-}

2. The formula of potassium ions is K^+ and bromide ions is Br^-. The formula of potassium bromide is:

A K_2Br_2 **B** KBr_2 **C** KBr

3. The formula of calcium ions is Ca^{2+} and carbonate ions is CO_3^{2-}. The formula of calcium carbonate is:

A Ca_2CO_3 **B** $CaCO_3$ **C** $Ca_2(CO_3)_2$

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

WATER IN OUR ENVIRONMENT

We have seen that the compound water has the formula H_2O. The water that is found in seas, rivers and streams, and the water that comes to us through our taps contains many other substances. We all know that sea water has a salty taste. This is because sea water contains dissolved sodium chloride (salt). All 'natural' water supplies contain dissolved substances. In other words, water in our environment is a mixture.

> A **mixture** contains two or more types of substances. The different substances are not chemically bonded to each other..

Most water in our environment is a mixture of H_2O (water) and various other substances. These substances may include:

- dissolved gases such as oxygen
- metal ions such as magnesium, calcium, sodium and potassium ions
- negative ions such as hydrogencarbonate and nitrate ions
- pesticides
- organic matter
- parasitic microorganisms
- particulate matter.

Without dissolved oxygen fish could not survive in a river
Lee Sutterby / gettyimages

These dissolved substances are not necessarily harmful; in fact they may be essential for life. Fish could not survive in water if there was no dissolved oxygen!

Fast moving rivers may often appear muddy or dirty after heavy rain. The river water contains small particles that are suspended in the water. The particles are not dissolved. If you collect the water, the particles will slowly settle out.

River water containing particulate matter
Crissy1982 / gettyimages

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

HOW DO SUBSTANCES GET INTO WATER?

From rainwater

Rain falls from clouds to the earth. As it does so, it falls through air which contains nitrogen, oxygen and a little carbon dioxide. As a rain drop falls some of these gases dissolve in the water.

Carbon dioxide also reacts with the water in the rain drop to form a slightly acidic solution.

The pH of the raindrop drops below 7 to 5.6.

All rain water is slightly acidic due to dissolved carbon dioxide
slobo / gettyimages

From minerals

Once the rain water falls onto the ground, some may evaporate, but most will soak into the ground or run into streams and rivers.

As the water runs over the ground it dissolves some ions contained in the minerals.

For example, in regions where there is limestone (calcium carbonate) the acidic rainwater reacts with the limewater so that the water contains dissolved calcium and hydrogen carbonate ions.

Cheddar Caves, Somerset
David Wall / Alamy Stock Photo

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

From agriculture


Fertiliser spread near rivers may wash into nearby rivers following heavy rain
Mike Dabell / gettyimages

Potassium nitrate dissolves in water. If a farmer has spread a fertiliser containing potassium nitrate on a field, it is possible that following heavy rain some of the fertiliser will dissolve in rain water and wash off the field into rivers. The water will contain potassium and nitrate ions.

From untreated sewage

Harmful bacteria can enter water supplies because of poor treatment of sewage.

The summer of 1849 saw one of the last major outbreaks of cholera in Swansea which caused over 150 deaths. Untreated water still brings disease and death to many in the undeveloped world.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

Our water supplies and sustainability

In the UK, every person uses approximately 150 litres of water a day. This is water that has been cleaned, treated and pumped from reservoirs, rivers and aquifers. Some of this water leaks out of pipes before it gets to the home.

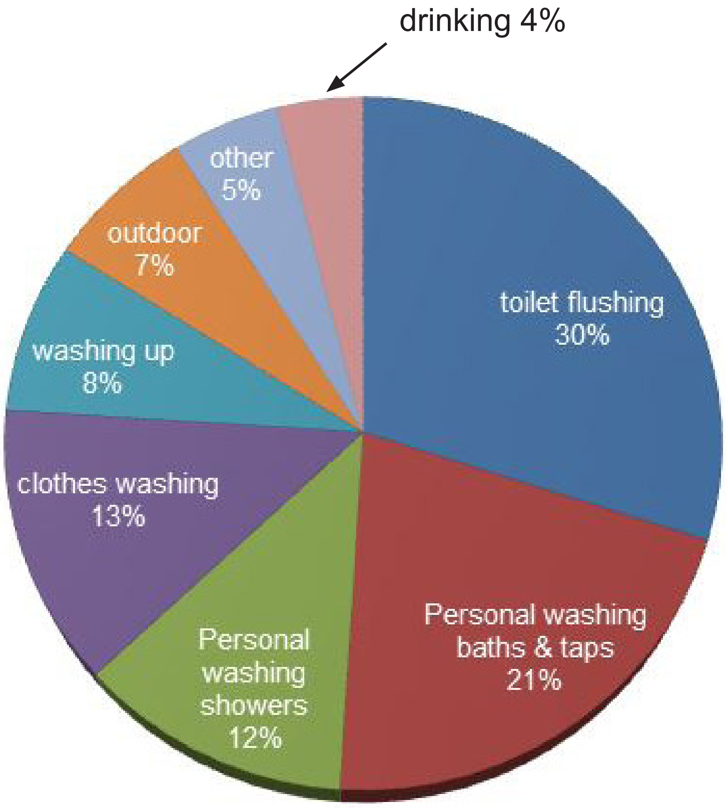
Only 4% of the water we use in our homes is for drinking.

Water use in the home

The amount of water we need to sustain our lives is greater than the 50 litres a day we use in our homes. If we take into account the water that is needed to produce the food and products we use we each consume 3 400 litres per day.

When we take into account the size of the population, the UK has less available water per person than most European countries!

Water is an important resource which needs to be used **sustainably.**



> **Sustainability** is about taking what we need to live now, without putting at risk the ability of people in the future to meet their needs.

If an activity is said to be sustainable, it should be able to continue forever.

Living sustainably is about living within the means of our environment and ensuring that our lifestyle doesn't harm other people.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

Extracting water from rivers can cause environmental damage particularly after long periods of dry weather. If a lot of water is taken out of a river, the river water levels may fall which may lead to a build-up of chemicals that upset the ecosystem. Some reports suggest that the current use of water from rivers and groundwater sources is so high that it would take the equivalent of 23 million people to stop using water every day to get back to environmentally sustainable levels.

Obtaining drinking water

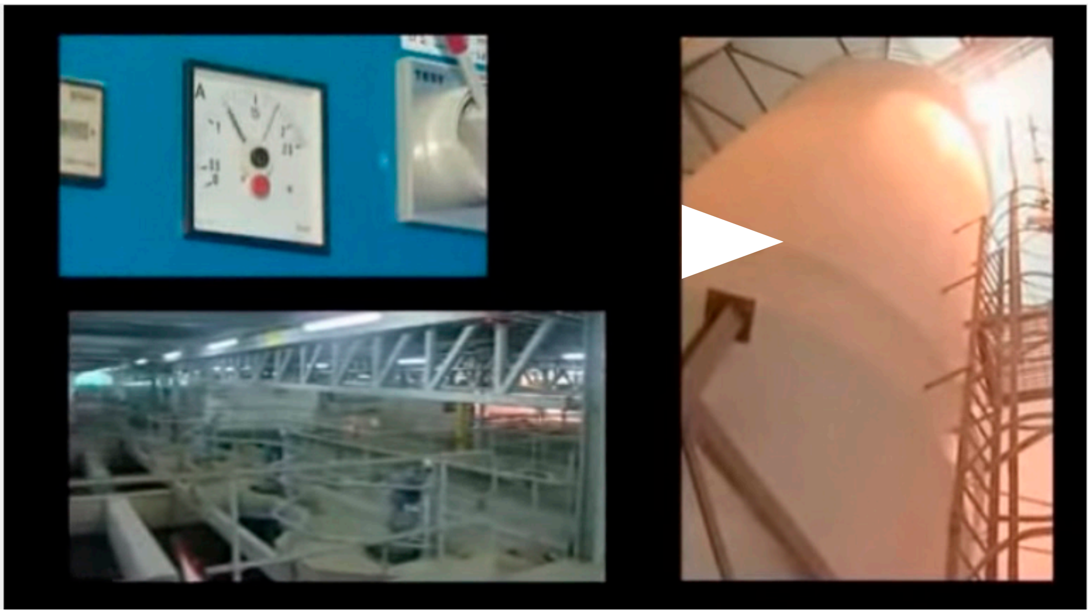
The area served by Welsh Water receives more rain overall than most other parts of the UK. The wettest area is Snowdonia with up to 6 000 mm rainfall a year. Some of that rain runs into rivers and collects in reservoirs where it can be used to provide water for us to drink. 97% of our water in Wales comes from surface water. Some important steps in the distribution of water to our homes are shown below.

Reservoir	Large particles settle out by gravity in the resrvoir.
↓	
Filter Beds	Water is filtered through layers of sand and gravel removing smaller, insouluble particles.
↓	
Disinfection	The water must be disinfected to kill any remaining bacteria to make it safe to drink. This is usually done by adding chlorine or sometimes ozone.
↓	
Distribution System	Water is transported through water mains and pipes lying underground.
↓	
Home	

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

SOMETHING TO WATCH



A video describing how we get water is available at:

https://youtu.be/wpAdKQ2_gOY

or

http://www.dwrcymru.com/en/My-Water.aspx

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

---

1. 100 cm^3 of water flows out of a running tap every second Calculate how much water will be used if you leave the tap flowing for 2 minutes, the time you should take to clean your teeth.

The amount used will be:

A 200 cm^3
B 2 dm^3
C 12 dm^3

2. Stream water may appear clean. You should not drink it because it may contain:

A dissolved carbon dioxide
B dissolved calcium ions
C harmful bacteria

3. Spring water can be bottled and sold to customers through supermarkets.
The spring water:

A is a mixture which contains some ions and gases
B does not contain any dissolved gases
C is purified to remove dissolved ions

4. This question concerns the purification of water before it is distributed to our homes Select the correct words from the brackets below:

Water is filtered through layers of sand and gravel in order to remove (**soluble materials / small particles**).

The water must be disinfected to make it safe to drink. Disinfection (**removes harmful chemicals / kills microorganisms**).

(**Chlorine / Bromine / Oxygen**) is used to disinfect the water.

Desalination

About 97% of the water on Earth is seawater and is unsuitable for drinking due to the high salt content. However, pure water can be produced from sea water.

The process to remove the salts from water is known as **desalination.**

Desalination provides fresh water where there may be limited supplies of naturally occurring freshwater. There are two ways that we can desalinate seawater. By using:

- distillation
- a membrane system

Distillation

The simplest form of desalination is distillation.

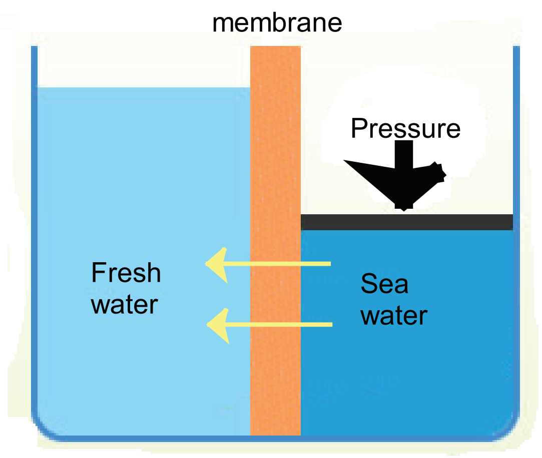
Distillation involves boiling sea water. The water vapour is then cooled and condensed to form pure water - leaving the salt behind.

There are disadvantages. The process:

- is expensive because of the large amounts of energy needed
- increases the use of fossil fuels to provide energy. Fossil fuels are non-renewable.
- increases carbon dioxide emissions as a result of using fossil fuels as an energy source.

Membrane systems

Another form of desalination involves using a membrane system. In this process the sea water is pressurised. Water passes through the membrane leaving the salty water on the other side.



More on distillation

Distillation can also be used to separate water from a solid, such as salt, as in desalination.

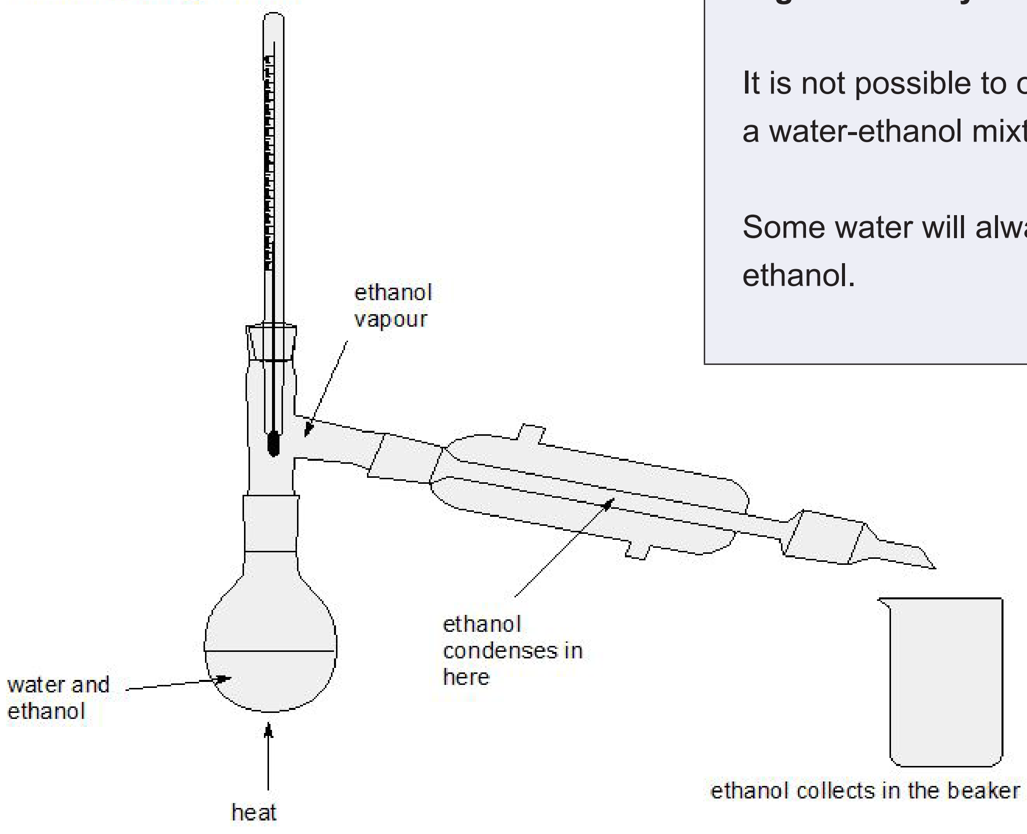
Distillation can also be used to separate two miscible liquids.

Miscible liquids are liquids that dissolve in each other.

Pure liquids have distinct boiling points. Distillation can separate liquids **if** they have **different** boiling points.

Water boils at 100°C and ethanol at 78°C. These two liquids can be separated by distillation. The liquid with the **lower** boiling point (ethanol) boils off first.

Distillation apparatus



Higher tier only:

It is not possible to obtain pure ethanol from a water-ethanol mixture.

Some water will always distil across with the ethanol.

Distillation is used in distilleries to make spirits such as whisky.

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

TEST YOURSELF

Complete the sentence using the best words/phrases from the box below.

away from	**near**	**cheap**	**expensive**

1. Desalination plants are normally built ……………..….the sea. It is an advantage if energy is ………………

Obtaining resources from our planet (Unit 1.2)

Obtaining clean water (specification 1.2.1)

SOLUBILITY CURVES

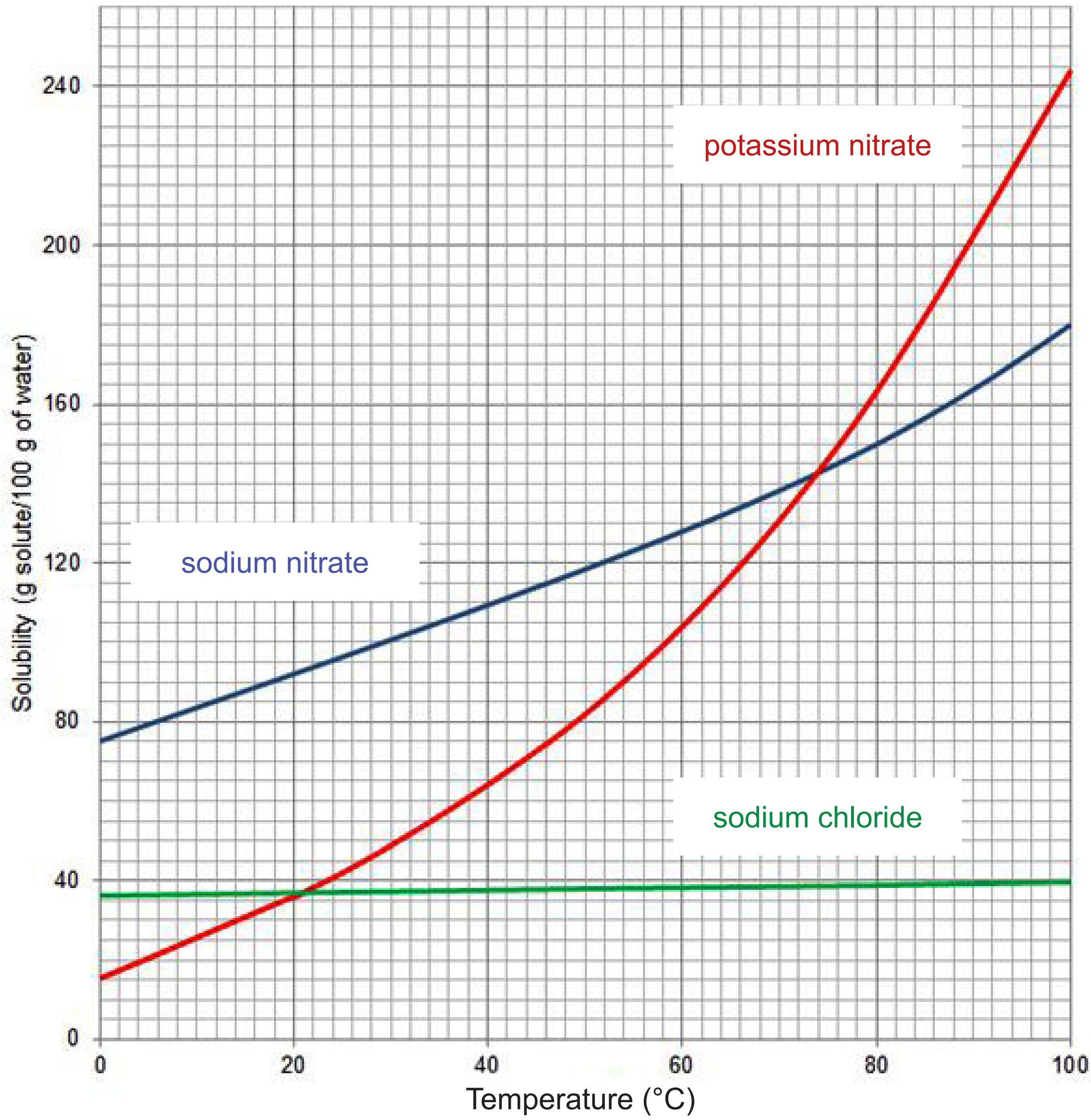
A **solution** is a mixture that results from dissolving a substance in a liquid.

A substance that is dissolved in a liquid is called a **solute.**

The liquid in which a solute dissolves is called the **solvent.**

Water is an example of a solvent. Propanone (nail vanish remover) is another.

Solubility curves show how many grams of a particular substance can be dissolved in a solvent. The solubility of salts can be very different.



Make sure you can read information from graphs such as the one above.

Try the questions on the next page. You must be able to answer questions like these for an exam.

TEST YOURSELF

Look at the solubility curve on the previous page to answer these questions:

1. The salt whose solubility hardly changes with temperature is:

A sodium nitrate
B sodium chloride
C potassium nitrate

2. The salt whose solubility increases most with temperature is:

A sodium nitrate
B sodium chloride
C potassium nitrate

3. The salt which has a solubility of 75 g / 100 g of water at 0°C is:

A sodium nitrate
B sodium chloride
C potassium nitrate

4. The solubility of potassium nitrate at 80°C is:

A 175 g / 100 g of water
B 155 g / 100 g of water
C neither of these values

HARD AND SOFT WATER

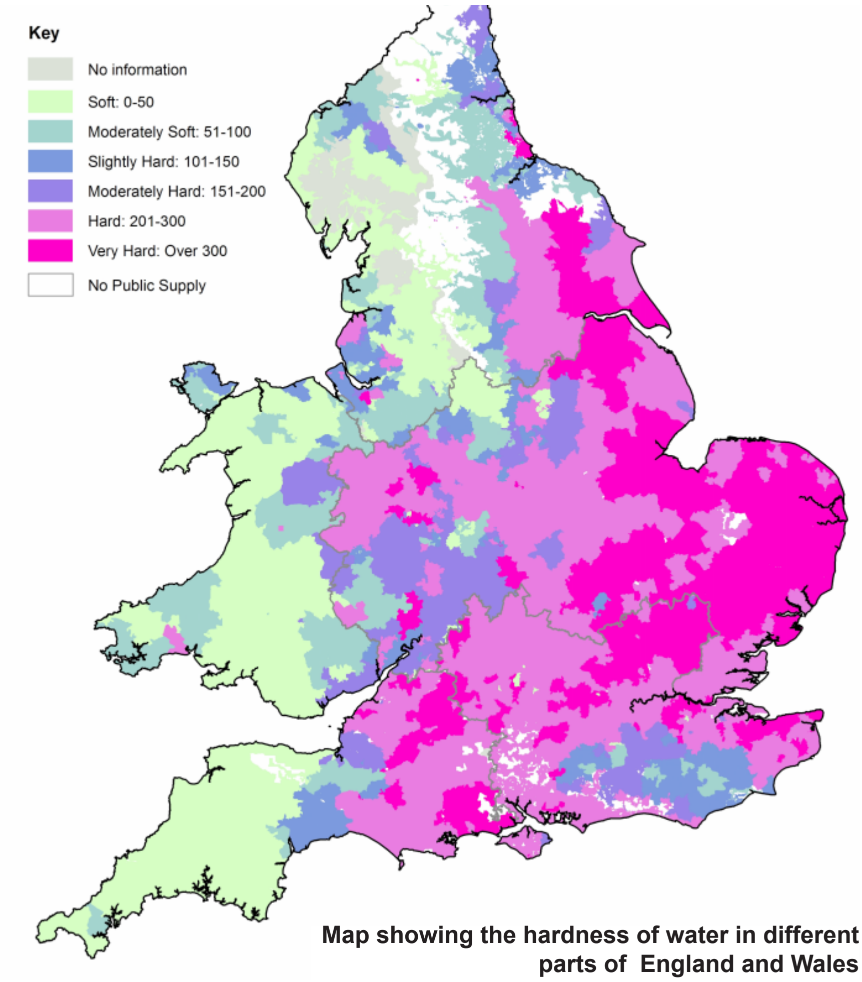
Water is often classed as ‘hard’ or ‘soft’. **Soft water** forms a lather with soap.

Soft water contains **very low levels** of calcium and magnesium ions.

On the other hand:

Hard water is water which does not readily form a lather with soap but causes a scum.

Hard water is caused by the presence of **calcium** or **magnesium ions.**



Map showing the hardness of water in different parts of England and Wales

© Crown Copyright.
http://www.dwi.gov.uk/index.htm

The hardness of water varies in different parts of the country.

The types of rock that water flows over determines how hard the water will be.

If water flows over limestone rocks ($CaCO_3$) some of the calcium ions dissolve in the water causing hard water.

Types of hardness

Temporary hard water can be softened by boiling it.

Temporary hard water contains dissolved hydrogencarbonate ions, HCO_3^-.

When heated, HCO_3^- decomposes (break down) to form carbonate ions, CO_3^{2-}.

The carbonate ions in the boiled water react with dissolved calcium and magnesium ions to form insoluble precipitates (calcium carbonate and magnesium carbonate).

Permanent hard water stays hard even when it is boiled.

Permanent hard water contains dissolved sulfate ions, SO_4^{2-}.

These do not decompose when heated. SO_4^{2-} ions remain dissolved and do **not** react with calcium and magnesium ions - so the water stays hard even when boiled.

Kettle element coated with limescale
John Smaller / Alamy Stock Photo

Pipe blocked with limescale
Sheila Terry / Science Photo Library

Advantages and disadvantages of hard water

Advantages	Disadvantages
Can improve the taste of the water	More soap is needed to produce a lather, which increases costs.
Can help to reduce heart disease *This happens with both temporary and permanent hardness.*	The scum also spoils the appearance of baths and shower screens.
	Temporary hardness reduces the efficiency of kettles and heating systems. This means more energy is needed to heat the water, increasing costs. This is because limescale (calcium carbonate) is produced when the water is heated which coats the heating element in kettles, and the inside of boilers. Pipes may also become blocked by limescale causing the heating system to break down.

Softening water

It can be beneficial to soften the wate .

Hard water can be softened by removing the calcium and magnesium ions.
There are **three** methods.

1. Boil water. This **only works for temporary hardness**. It is only useful for small quantities of water.

Higher tier only

$$Ca(HCO_3)_2(aq) \rightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$$

temporary hardness → *calcium removed*

2. Add washing soda (sodium carbonate).

   This **removes both temporary and permanent** hardness. The calcium ions combine with carbonate ions to form a precipitate of calcium carbonate. A simpler reaction occurs with the magnesium ion.

Higher tier only

$$Ca^{2+}(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2Na^{+}(aq)$$
$$Mg^{2+}(aq) + Na_2CO_3(aq) \rightarrow MgCO_3(s) + 2Na^{+}(aq)$$

3. Use an ion exchange column.

   This method **removes both temporary and permanent hardness**. An ion exchange column contains an ion exchange resin packed into tubes. These can be built into machines, such as a dishwasher.

   This is a continuous process. The resin needs regenerating every now and then by treating it with a concentreated solution of sodium chloride.

   The resin beads have sodium ions attached to them.

HIGHER TIER ONLY

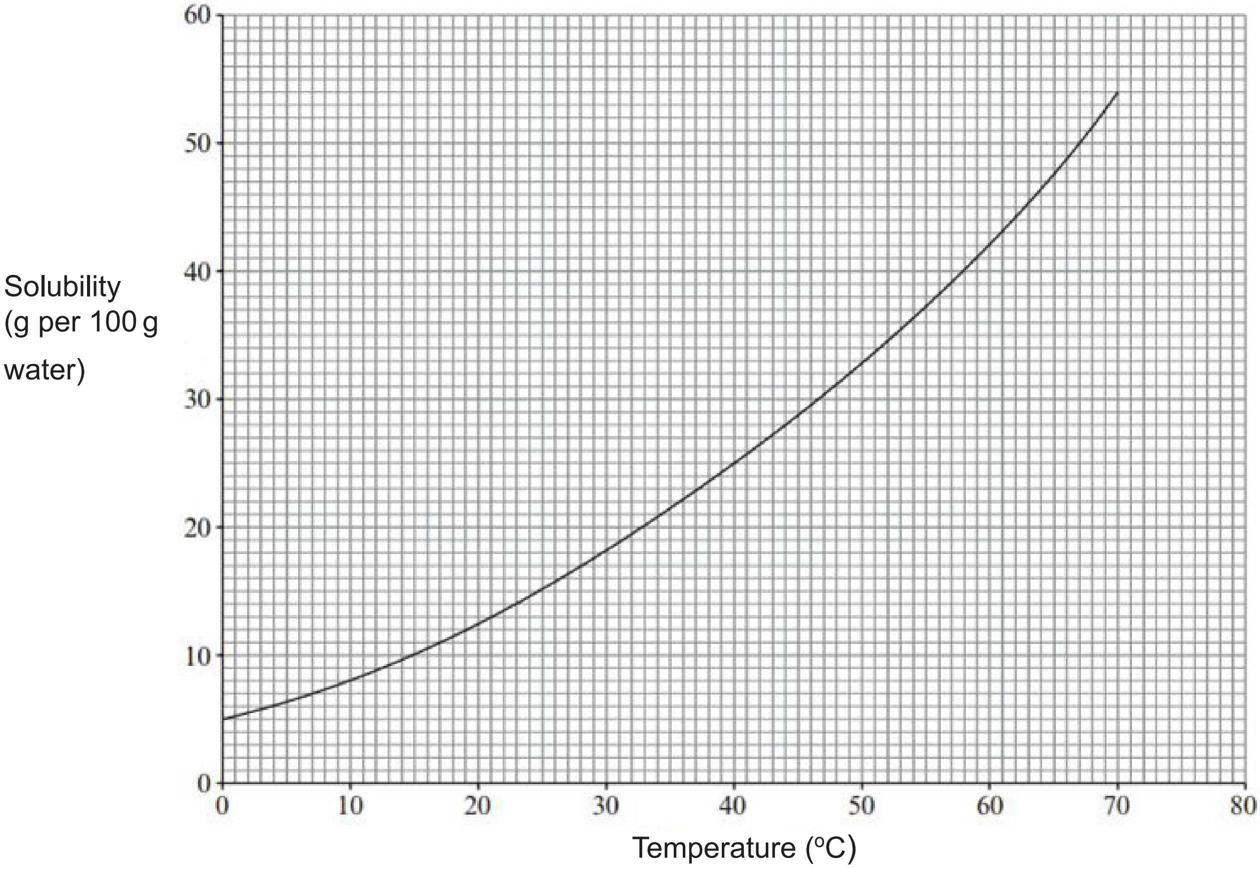
As the hard water passes through the column, the calcium and magnesium ions swap places with the sodium ions.

The calcium and magnesium ions are left attached to the beads, while the water leaving the column contains more sodium ions.

The hard water is softened because it no longer contains calcium or magnesium ions.

PRACTICE QUESTIONS

1. The graph below shows the solubility of potassium dichromate in water at different temperatures.



The table below shows the solubility of potassium chloride in water at different temperatures.

Temperature (°C)	0	20	40	60	80
Solubility (g per 100 g water)	28	34	40	46	52

(a) Plot the graph of the solubility of potassium chloride on the grid on page 110. **[3]**

(b) Using the graphs give

(i) the temperature at which the solubility is the same for both potassium chloride and potassium dichromate. **[1]**

temperature = ... °C

(ii) the difference between the solubilities of potassium chloride and potassium dichromate at 30°C. **[1]**

difference = ... g per 100 g of water

Obtaining resources from our planet (Unit 1.2)

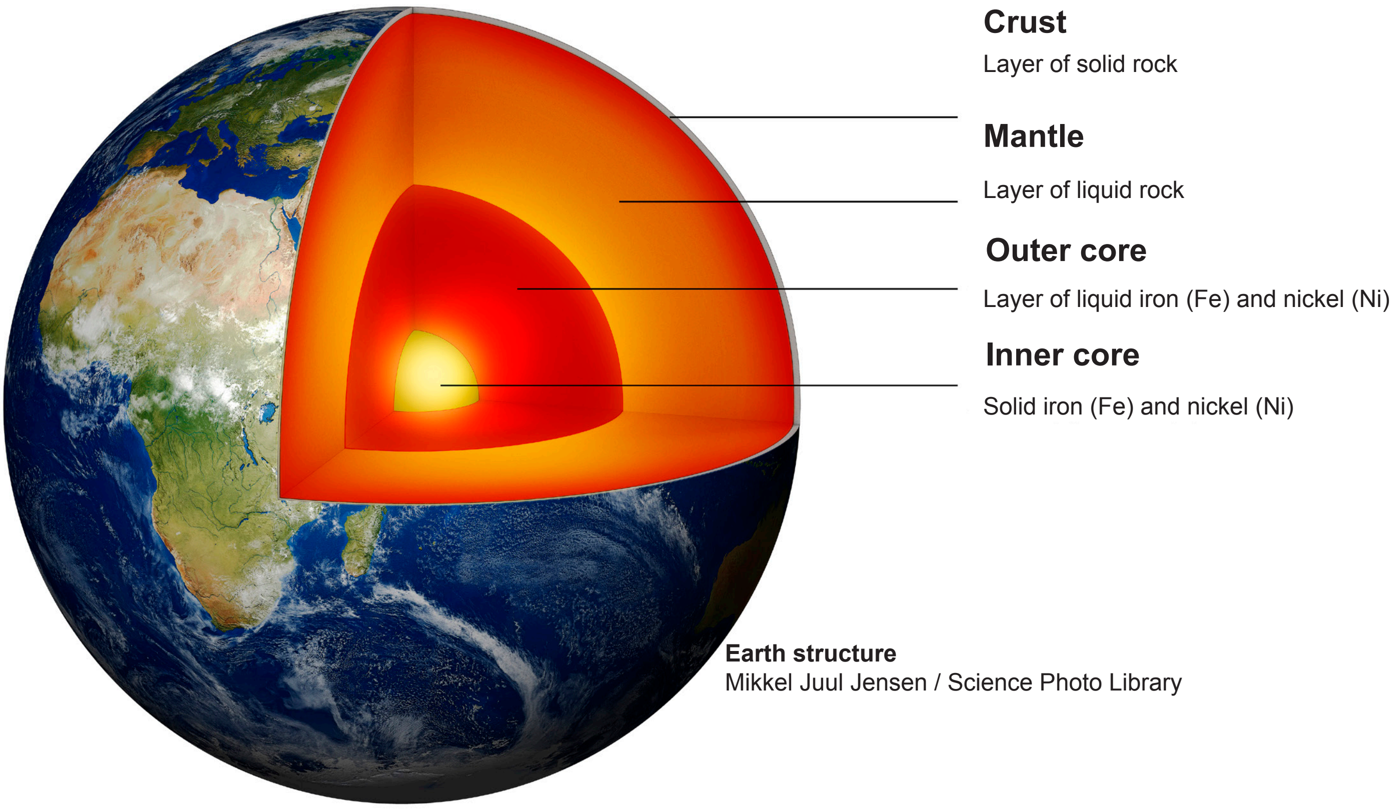
Resources from our planet (specification 1.2.2)

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

THE STRUCTURE OF THE EARTH

The **Earth** has a **layer structure** with a solid iron inner core, molten iron outer core, mantle and crust.



Earth structure
Mikkel Juul Jensen / Science Photo Library

The outer layer is very thin and has a low density.

The next layer down is called the mantle. This has the properties of a solid but can flow very slowly.

The outer core is made of liquid iron.

The inner core is made of solid iron.

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

Plate tectonics

The Earth's outer layer (the crust and rigid upper part of the mantle) is broken into a number of large pieces called **tectonic plates.**

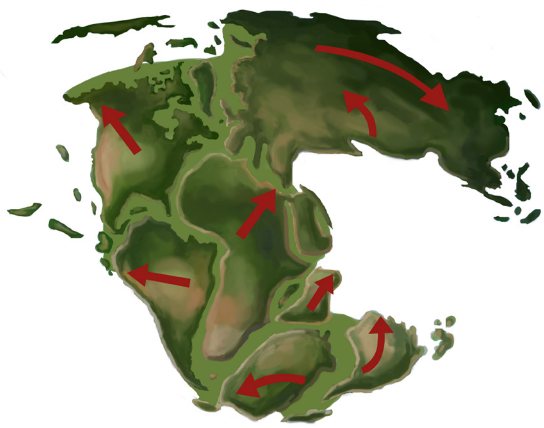
These plates continuously move at the rate of a few centimetres per year in relation to one another.

Continental drift

This theory was developed from Alfred Wegener's earlier theory of continental drift.

Wegener suggested that all of the continents were once joined together in a supercontinent called Pangaea, and they have since drifted apart.

This idea of continental drift is based upon the following observations:



Pangaea
Spencer Sutton / Science Photo Library

- jigsaw-like fit of the edges of continents e.g. the West coast of Africa and the East coast of South America
- similar rocks of the same age found on the different continents
- similar plant and animal fossils found on opposite sides of the oceans

Wegner's theory did not attempt to explain how the continents drifted apart and was rejected by many scientists at the time.

Convection currents were proposed by some scientists in the 1930s and were generally accepted as correct in the 1960's.

Convection currents cause the Earth's plates to move a few centimetres each year.

Today Wegener's theory has been refined and is known as**plate tectonics.**

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

SOMETHING TO WATCH

Watch a video showing the divide between two of the Earth's plates and how the plates move.
http://www.bbc.co.uk/science/earth/surface_and_interior/plate_tectonics#p00fztvj

Processes occurring at plate boundaries

Tectonic plates move. There are three ways which they move relative to each other.

At a **constructive boundary**, the plates move apart.

The plates move apart due to convection currents inside the Earth.

As the plates move apart, magma rises from the mantle. When the magma reaches the surface, it cools and solidifies to form a new crust of igneous rock. Eventually the new rock builds up to form a volcano. There may also be earthquakes.

Constructive boundaries tend to be found under the sea, e.g. the Mid Atlantic Ridge.

At a **destructive boundary** the plates move towards each other.

This usually involves a continental plate and an oceanic plate.

The oceanic plate is denser than the continental plate so, as they move together, the oceanic plate is forced underneath the continental plate. As the oceanic plate is forced below the continental plate it melts to form magma and earthquakes are triggered.

As the plates push together, the continental crust is squashed together and forced upwards. creating fold mountains such as the Himalayas and the Alps.

At a **conservative boundary** the plates slide past each other.

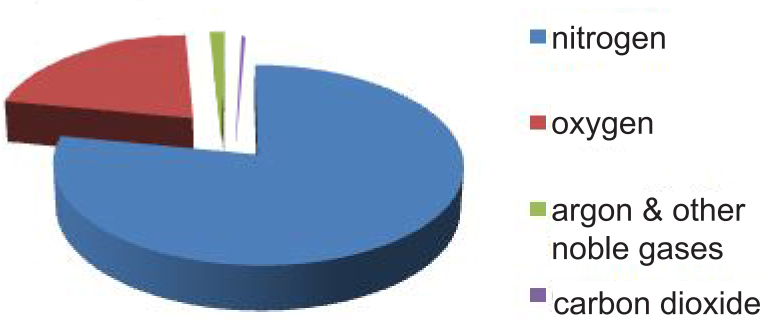
Powerful earthquakes may occur but there are **no** volcanos at this type of boundary because melting does not occur.

THE EARTH'S ATMOSPHERE

Today's atmosphere

The composition of the atmosphere today:

nitrogen 78%
oxygen 21%
argon (and other noble gases 0.9%)
carbon dioxide 0.04%



The early atmosphere

There are several theories about how the Earth's atmosphere may have formed and changed with time.

One idea is that the early atmosphere of the Earth was formed from the gases given out by volcanoes. It is believed that there was intense volcanic activity on the early Earth.

Carbon dioxide, water vapour and ammonia make up the greatest proportion of **volcanic gases.**

The early atmosphere was probably mostly carbon dioxide with little or no oxygen. There were smaller proportions of water vapour, ammonia and methane.

As the Earth cooled down, most of the water vapour condensed and formed the oceans.

The atmosphere then changed over time to produce the atmosphere we have today.

Volcanic eruption, Italy
Prisma Bildagentur AG / Alamy Stock Photo

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

In photosynthesis carbon dioxide is changed into oxygen. As plants evolved and spread over the Earth's surface, the plants started to use carbon dioxide in photosynthesis and produced oxygen. Carbon dioxide levels in the atmosphere fell and oxygen levels increased.

Marine animals then began to evolve. As a result, some of the carbon was used to form shells. When these animals died their shells formed limestone and chalk, this locked some carbon dioxide from the atmosphere.

Even more of the carbon was locked up in coal formed from larger plants, and crude oil and natural gas formed from marine organisms.

The ammonia in the Earth's atmosphere reacted with oxygen to release nitrogen.

Chalk cliff face

tbkmedia.de / Alamy Stock Photo

TEST YOURSELF

Select the correct answer(s) from the brackets in each case.

1. Approximately (**5% / 20% / 50% / 75%**) of today's atmosphere is made of oxygen.

2. Volcanos release gases into the atmosphere. The three main gases they release are (**oxygen / carbon dioxide / ammonia / methane / water vapour)**.

3. In photosynthesis (**oxygen / carbon dioxide / ammonia / methane**) is changed into (**oxygen / carbon dioxide / ammonia / methane**).

THE PERIODIC TABLE

The Periodic table is an ordered list of all the elements. **Some** elements from the Periodic Table are shown below.

Groups

Non-metals

Metals

Periods	1	2											3	4	5	6	7	8
1									H									He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr											In	Sn	Sb	Te	I	Xe
6	Cs	Ba											Ti	Pb	Bi	Po	At	Rn
7	Fr	Ra																

Columns of elements are called **groups.**

The group number tells us the number of electrons in the outer shell.

Group **1** elements are Li, Na, K, Rb, Cs, Fr. They all have 1 electron in their outer shell.

Group **7** elements are F, Cl, Br, I, At. They all have **seven** electrons in their outer shell.

Rows of elements are called **periods.**

The period number tells us the number of shells that are occupied in the atom.

Period 2 elements are Li, Be, B, C, N, O, F and Ne.

Metals are found on the **left hand** side of the periodic table (shown in red above).

Non-metals are found on the **right hand** side of the periodic table (shaded in blue above).

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

Groups of elements and properties

Groups of elements have similar electronic, chemical and physical properties.
The chemical and physical properties normally show gradual changes down a group.

You need to be able to examine data to establish trends and make predictions.

You do not need to learn the data but understand what it tells you.

Some examples are given below.

Group 1 (alkali metals)

Group 1 elements all have similar physical and chemical properties.

They are reactive metals. They all form ions with a +1 charge in their compounds.

The following table gives some physical properties of the alkali metals (group 1 metals).

Element	Atomic radius (pm)	Melting point (°C)
Li	167	180
Na	190	97
K	243	**?**
Rb	**?**	39
Cs	298	29

What can we learn from this information?

1. The atoms get larger down the group as more shells of electrons are added.
    - **Prediction:** The atomic radius of rubidium will be between 243 pm and 298 pm (it is actually 265 pm).
2. They have low melting points for metals.
3. The melting point decreases down the group.
    - **Prediction:** The melting point of potassium is between 39°C and 97°C. (It is actually 63°C).

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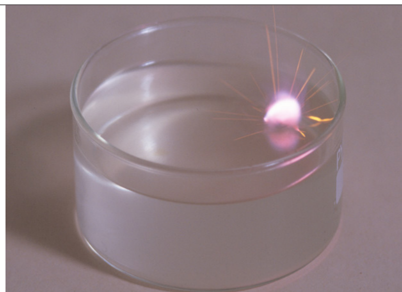
Resources from our planet (specification 1.2.2)

Chemical properties of group 1

They all have 1 electron in the outer shell (see earlier for electronic structure).

Element	Electronic structure
Li	2,1
Na	2,8,1
K	2,8,8,1

In their chemical reactions, they want to lose the outer electron to form a positive ion.

Element	Reaction with water	
Li	Floats on water. It fizzes steadily.	 sciencephotos / Alamy Stock Photo
Na	Metal forms molten ball and moves around surface. It fizzes rapidly.	
K	The metal burns rapidly on the surface of the water It bursts into flam	 sciencephotos / Alamy Stock Photo

This table shows us that group 1 metals are:

- all reactive;
- become more reactive down the group.

Group 7 (the halogens)

Group 7 elements (also called the halogens) are all non-metals with 7 electrons in the outer shell.

Physical properties

Element	Atomic radius - (pm)	Melting point - (°C)	Colour (of gas)
F	42	-220	pale yellow
Cl	**?**	-102	yellow green
Br	94	**?**	red-brown
I	115	114	purple

What can we learn from this information?

1. The atoms get larger down the group as more shells of electrons are added.
2. The melting point increases down the group.
3. The halogens are all coloured and become darker down the group

Chemical properties of group 7

Element	Reaction with iron
F	Cold iron wool burns in cold fluorin
Cl	Reacts with heated iron wool very quickly
Br	Bromine has to be warmed and iron wool heated
I	Has to be heated strongly - the reaction is slow

SOMETHING TO WATCH

Watch a video of the halogens reacting with iron wool.

https://youtu.be/EvtyMr5EvBY (Royal Society of Chemistry)

https://www.youtube.com/channel/UCRaqrYgbZAdqCl-_tpG150Q

TEST YOURSELF

1. The elements of group 1 (in order) are: Li, Na, K, Rb and Cs.

   Look at information on the reactions of lithium, sodium and potassium with water. Predict which of the following you are likely to see if a small piece of rubidium is added to water by underlining the correct words to finish the sentence

   Rubidium will react (**explosively / rapidly / slowly**) with water.

2. Look at the table of the physical properties of the halogens.

   (a) The atomic radius of chlorine is:

   A less than 42 pm
   B between 94 and 115 pm
   C between 42 and 94 pm

   (b) The melting point of bromine is:

   A between -220 and -102°C
   B between -102 and 114°C
   C more than 114°C

3. The halogens need to gain one electron to fill their outer shell
   The atomic number of chlorine is 17.

   The electronic configuration of the chloride (Cl^-) ion is:

   A 2,8,7
   B 2,8,6
   C 2,8,8

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

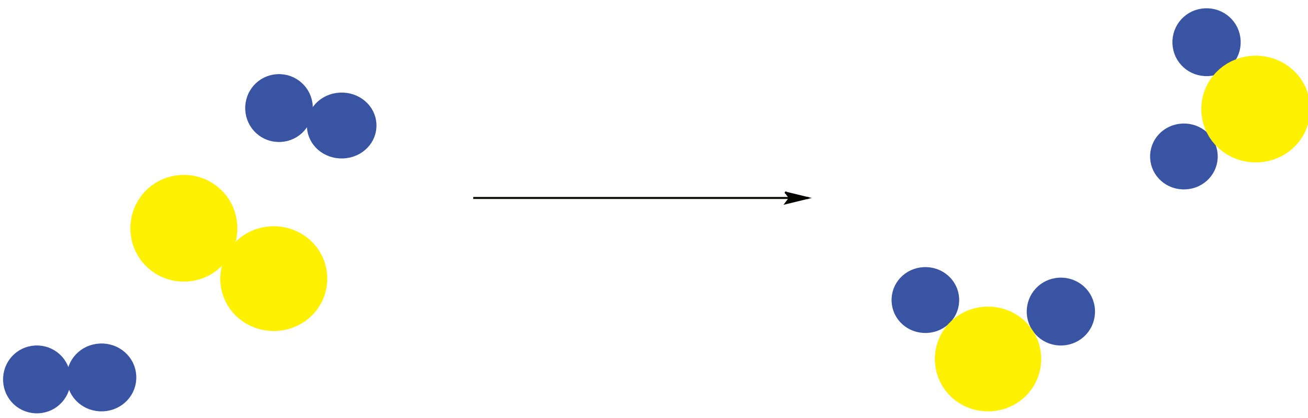
CHEMICAL REACTIONS

A chemical reaction involves changing one set of chemical compounds into another.

In a **chemical reaction** atoms are rearranged to make new products.

No atoms are lost in the process.

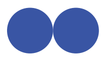
Example

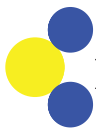


Mixture of hydrogen and oxygen

Water

The above diagram shows how atoms rearrange to form water.

On the left hand side, we have molecules of hydrogen () and oxygen ( ).

The atoms rearrange to form water molecules on the right hand side ().

We can show the changes in a chemical equation:

Word equation: hydrogen + oxygen → water

Balanced symbol equation: $2H_2 + O_2 \rightarrow 2H_2O$

Writing symbol equations

Symbol equations are very useful because they give us exact information on the number of atoms or molecules involved in the chemical change.

To be able to write a symbol equation you need to know the chemical formula.

The chemical formula of a particular compound is fixed and should not be changed to make an equation ‘work’.

Some important formulae you **must** know are in the table below.

Name	Formula	Name	Formula
hydrogen	H_2	bromine	Br_2
oxygen	O_2	iodine	I_2
nitrogen	N_2	All other elements	symbol only
fluorin	F_2	e.g. sodium	Na
chlorine	Cl_2	e.g. magnesium	Mg

You should also be able to work out the formula of simple compounds.

You may want to revise ‘Working out the formula of simple compounds’ before going any further with this section.

Example 1

Sodium reacts with chlorine to form sodium chloride.

Word equation: **sodium + chlorine → sodium chloride**

First Find the formulae of the reactants and products.

Name	Formula
sodium	Na
chlorine	Cl_2
sodium chloride	NaCl

Second Write down the symbols in place of the reactants and products.

$$\mathbf{Na + Cl_2 \rightarrow NaCl}$$

The symbol equation is not finished. Symbol equations must have exactly the same number of each atom on either side of the arrow. At the moment we have 2 chlorine atoms on the left hand side and only one chlorine atom on the right hand side.

We must have the same number of each atom on both sides but not change the formula.

Third We will put a number '**2**' in front of 'NaCl':

$$\mathbf{Na + Cl_2 \rightarrow 2NaCl}$$

On the right hand side we now have 2 sodium and 2 chlorine atoms
On the left hand side we have 1 sodium and 2 chlorine atoms

Finally We need to balance sodium atoms by putting a '**2**' in front of Na:

$$\mathbf{2Na + Cl_2 \rightarrow 2NaCl}$$

The equation is now balanced with the same number of atoms on both sides of the equation.

Example 2

Magnesium reacts with chlorine to form magnesium chloride:

Word equation: **magnesium + chlorine → magnesium chloride**

First Find the formulae of the reactants and products.

Name	Formula
magnesium	Mg
chlorine	Cl_2
magnesium chloride	$MgCl_2$

Second Write down the symbols in place of the reactants and products.

$$\mathbf{Mg + Cl_2 \rightarrow MgCl_2}$$

On the left hand side we have 1 'Mg' and 2 'Cl' atoms
On the right hand side we also have 1 'Mg' and 2 'Cl' atoms

The equation is balanced!

EXTENSION WORK

Sometimes chemical equations include the symbols (s), (l), (g) and (aq). These tell you the state of the chemical compound in a reaction.

(s) solid
(l) liquid
(g) gas
(aq) aqueous (This means dissolved in water)

Example

$$2Na(s) \quad + \quad Cl_2(g) \quad \rightarrow \quad 2NaCl(s)$$

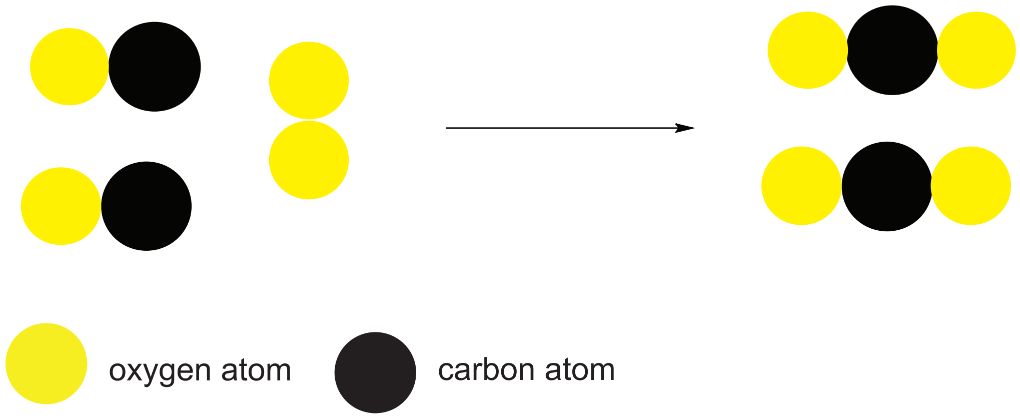
This tells you that sodium was a solid and chlorine was a gas when they reacted.
Sodium chloride was formed as a solid in the reaction.

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

TEST YOURSELF

1. Use the diagram below to work out the symbol equation for the reaction between carbon monoxide and oxygen gas.



The symbol equation is:

A $CO + O \rightarrow CO_2$

B $2CO + 2O \rightarrow 2CO_2$

C $2CO + O_2 \rightarrow 2CO_2$

2. The balanced symbol equation for magnesium reacting with oxygen to form magnesium oxide is:

A $Mg + O \rightarrow MgO$

B $Mg + O_2 \rightarrow MgO_2$

C $2Mg + O_2 \rightarrow 2MgO$

3. The balanced symbol equation for carbon reacting with oxygen to form carbon dioxide is:

A $C + 2O \rightarrow CO_2$

B $C + O_2 \rightarrow CO_2$

C $C + O \rightarrow CO$

TEST YOURSELF

4. Sodium and oxygen react together.

☐ $Na + O_2 \rightarrow$ ☐ NaO

To balance the equation you put:

A **1** in front of Na; **2** In front of NaO_2

B **2** In front of Na 2; **1** in front of NaO_2

C **2** In front of Na 1; **2** in front of NaO_2

PRACTICE QUESTIONS

1. (a) Lithium, sodium, potassium and rubidium are the first four members of Group 1 in the Periodic Table.

The following table gives the melting points and boiling points of lithium, potassium and rubidium.

Element	Melting point (°C)	Boiling point (°C)
lithium	180	1330
sodium	-	-
potassium	64	774
rubidium	39	688

Using the information in the table, choose from below the pair of values most likely to be the melting point and the boiling point of sodium. [1]

Pair A	Pair B	Pair C	Pair D
59 910	113 735	98 890	134 1498

(b) Sodium reacts vigorously with chlorine. Balance the symbol equation for the reaction between sodium and chlorine. [1]

$$\square\ Na + Cl_2 \rightarrow \square\ NaCl$$

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

OBTAINING RAW MATERIALS

In order to manufacture products we first need to obtain raw materials from the Earth s crust.

The method we use to obtain a raw material depends upon a number of factors.

These are some questions we need to think about when we obtain a raw material.

What physical state is the raw material in? Is it a gas, liquid or solid?

Where is it? Is it buried near the Earth’s surface, deep under the Earth’s surface?

Is it under dry land or under the sea?

What are the properties of the material we are obtaining?

Examples

Surface mining

An ore is a naturally occurring rock that contains metal or metal compounds in sufficient amounts to make it worthwhile to extract them. Iron ores contain compounds of iron such as iron(III) oxide. Iron ore, like many other ores, is obtained by **surface mining.**

Surface mining is done by removing (stripping) surface vegetation, dirt, and, if necessary, layers of bedrock in order to reach buried ore deposits.

Surface mine
Maxine House / Alamy Stock Photo

SOMETHING TO WATCH

Watch a video showing the mining of iron ore in Australia:

https://www.youtube.com/watch?v=X9daWUZbkxE

Subsurface mining

Subsurface mining may be used to obtain raw materials buried deep underground.

It consists of digging tunnels or shafts into the earth to reach buried ore deposits. Ore, for processing, and waste rock, for disposal, are brought to the surface through the tunnels and shafts.

Subsurface mining was once used in Cornwall to obtain tin ore.

Paldark tin mine in Cornwall
tony french / Alamy Stock Photo

Advantages and disadvantages of mining

Mining is essential if we are to obtain the natural resources we need to maintain modern life. As long as we use steel we will need to mine iron ore to produce the steel we need.

Mining has benefits but it also has drawbacks.

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

Benefit

Mining creates jobs. It provides people with useful employment. In this way it also helps support the economy in an area. It also gives us the much needed resources to help maintain modern life.

Drawbacks

Mining can damage the environment. Mining operations look unpleasant. They may cause dust and noise. Also, there will be increased traffic in the area leading to air pollution.

In the UK, there are now laws in place that must be followed by mine operators. These are designed to find a balance between human and environmental needs. These laws are intended to help make sure that mining is sustainable and both short term and long term damage to the environment is kept to a minimum.

Mining operations from old mine works were not governed by modern laws. As a result some areas still suffer from historic mining operations.

Spoil tips (mine waste tips) can still be found from old mining operations. These may not only be unsightly but also may contain waste which is poisonous to living systems. For example, old copper mines have left waste containing copper.

Old mine waste tips or spoil heaps on the flanks of Coniston Old man in the Copper Mines Valley above Coniston, Lake District
Paul Heinrich / Alamy Stock Photo

Obtaining salt

We can obtain salt via:

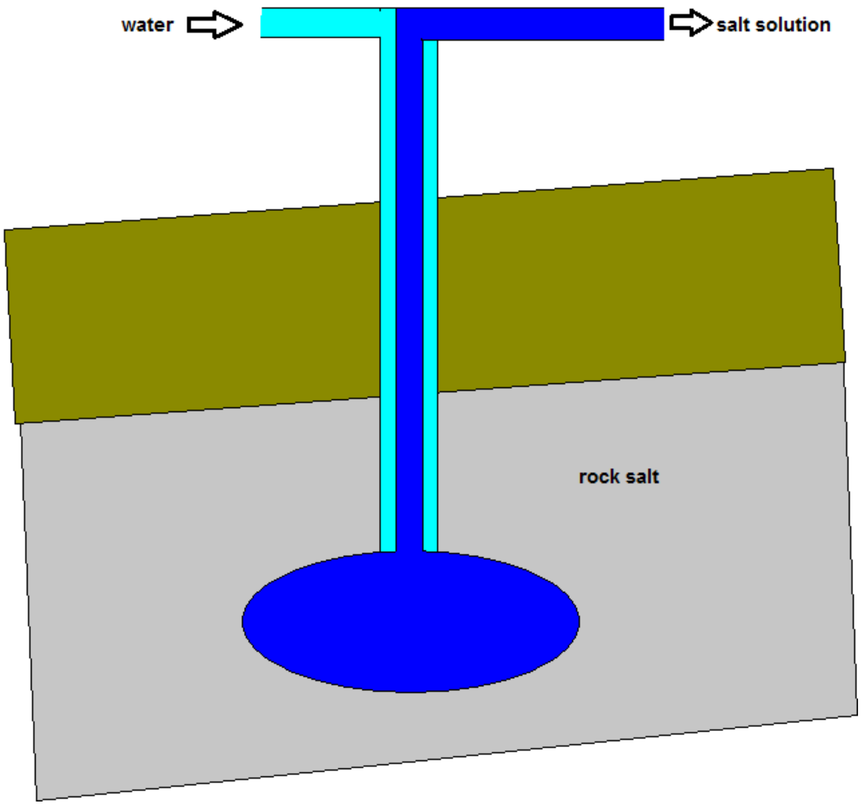
- deep shaft mining
- solution mining.

Rock salt can be mined using **deep-shaft mining.**

Underground excavator in a salt mine
imageBROKER / Alamy Stock Photo

Solution mining

Since salt also dissolves in water, solution mining has also been used. In solution mining water is pumped down into the salt vein and brought back to the surface as a solution of salt.



Drilling for gas and oil

Oil rig
Image Source / Alamy Stock Photo

Natural gas and crude oil is mainly obtained by **drilling.**

At sea, oil rigs need to be used which are anchored to the sea floor so that the oil can be pumped to the surface.

Impacts

Crude oil is a natural resource which is essential for modern life. Oil production, particularly from the North Sea, has made an extremely important contribution to the UK economy. It has not only helped the national economy but boosted local economies by providing well paid employment.

However, there can be drawbacks from obtaining this key resource. Spills of oil from drilling operations or from oil tankers can have serious environmental consequences.

The largest oil spill to date occurred in the Gulf of Mexico in 2010. Following an explosion on an oil rig, oil flowed out of the well into the Gulf of Mexico for 87 days until it was capped. The oil spill had a serious impact on marine life throughout the food chain.

In the short term many birds died as well as dolphins. Toxins also entered the food chain.

Oil may not only leak from oil wells. There have been a number of spills from **oil tankers** that have caused serious harm to marine life, in particular sea birds. Beaches may also become contaminated with crude oil.

One bird killed in Gulf of Mexico oil spill disaster
Nathan Allred / Alamy Stock Photo

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

Fracking

Fracking is a controversial method of obtaining natural gas from the Earth's crust.

Fracking involves drilling down into the earth and then pumping high-pressure water into the rock to release the gas inside.

Water, sand and chemicals are then injected into the rock at high pressure which forces the gas to flow out to the head of the well.

Fracking
CHROMORANGE / Ohde / Alamy Stock Photo

SOMETHING TO WATCH

Watch three short videos which explain how fracking works, why it is controversial and its potential benefits:

http://www.bbc.co.uk/newsround/23513694

Obtaining nitrogen and oxygen

Gases such as nitrogen or oxygen are obtained from **dry** air using **fractional distillation**. Oxygen and nitrogen have different boiling temperatures which allow us to separate them.

Fractional distillation uses a large column to separate the gases. The temperature is higher at the top than the bottom.

PROCESSING RAW MATERIALS

The raw materials we obtain are often not in a fit condition to use. They need to be processed.

Processing raw materials may require physical processes (e.g. separation) and chemical processes to transform the raw material into something useful.

For example, iron ore contains iron as the compound iron(III) oxide. We must chemically separate the iron from the oxygen.

Crude oil is a complex mixture. The mixture needs separating into simpler more useful fractions. This makes use of the **physical** properties (boiling points) of the different components. We also need to chemically change some of the materials from crude oil so we can obtain useful materials such as plastics.

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

TEST YOURSELF

1. Subsurface mining involves:

   A digging tunnels or shafts into the Earth
   B removing (stripping) surface vegetation, dirt, and, if necessary, layers of bedrock in order to reach buried ore deposits
   C removing layers of bedrock in order to reach buried ore deposits

2. Salt can be obtained by:

   A drilling
   B fracking
   C solution mining

3. An example of **chemical** processing of a raw material is:

   A separation of the different fractions of crude oil
   B separating iron from oxygen in iron oxide
   C fracking

Processing crude oil

Crude oil is a very thick dark liquid.

It is a complicated mixture of many different compounds, mostly hydrocarbons. Hydrocarbons contain the elements carbon and hydrogen.

Crude oil needs to be processed before it can be used. Many useful products can be obtained from crude oil.

Crude oil
Science Photo Library

Processing involves a number of steps. This work is carried out in an **oil refinery.**

Oil refiner , Milford Haven
Martin Bond / Science Phoyo Library

An **oil refinery** is an industrial plant where crude oil is processed and refined into more useful products.

Separating the mixture

We have already seen that we can separate two liquids dissolved in each other by using distillation. Crude oil is a complex mixture of hydrocarbons each having a different boiling point. Fractional distillation allows us to separate more complex mixtures.

We can do this in the laboratory by adding a tall column above the mixture.

> Crude oil is separated into simpler mixtures called fractions by **fractional distillation.**

Fractional distillation
Andrew Lambert Photography / Science Photo Library

Fractionating columns in a refiner
Paul Rapson / Science Photo Library

An oil refinery also uses fractional distillation to separate the complex mixture of hydrocarbons.

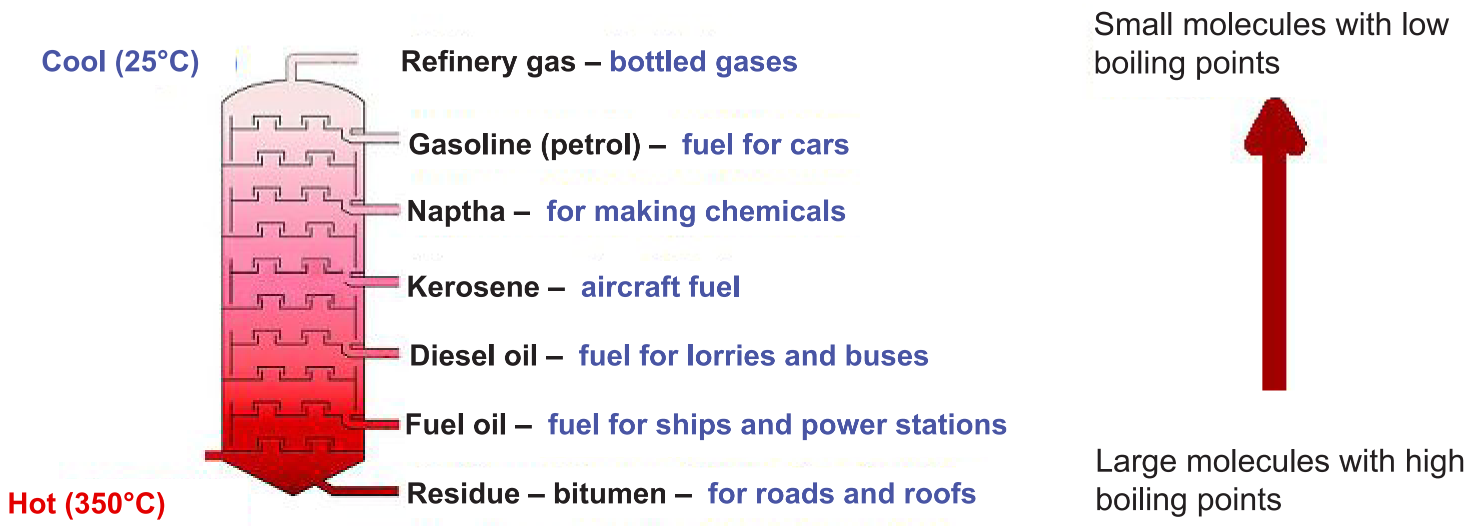
The column is hot at the bottom and cool at the top.

Substances with high boiling points condense at the bottom and substances with lower boiling points condense on the way to the top.

The crude oil is evaporated and its vapours condense at different temperatures in the fractionating column.

Each fraction contains hydrocarbon molecules with a similar number of carbon atoms.

The diagram below shows the main fractions of crude oil:



Cracking

Some of the large molecule hydrocarbons that were separated in fractional distillation of crude oil are not very useful.

These large molecules can be converted into smaller and more useful molecules by a process known as **cracking.**

This is carried out by heating the hydrocarbons over a catalyst. This converts the long molecules into smaller more useful molecules.

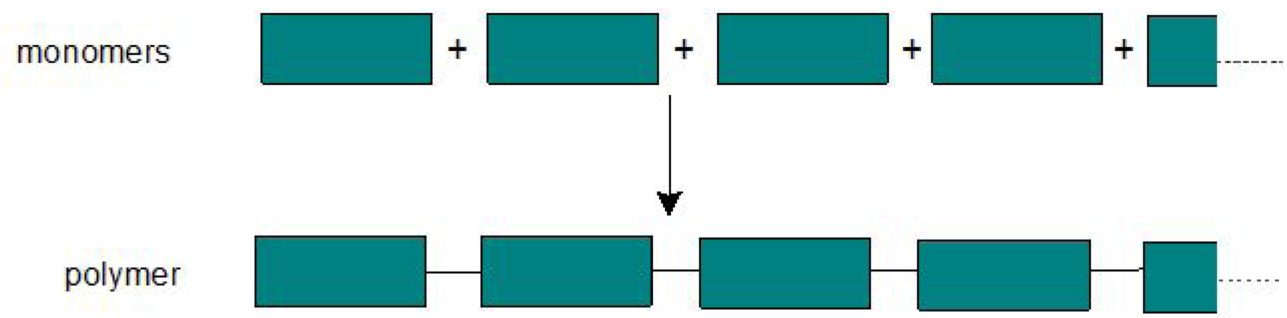
Cracking produces some, small reactive molecules called **monomers** which can be used to make plastics.

Polymerisation

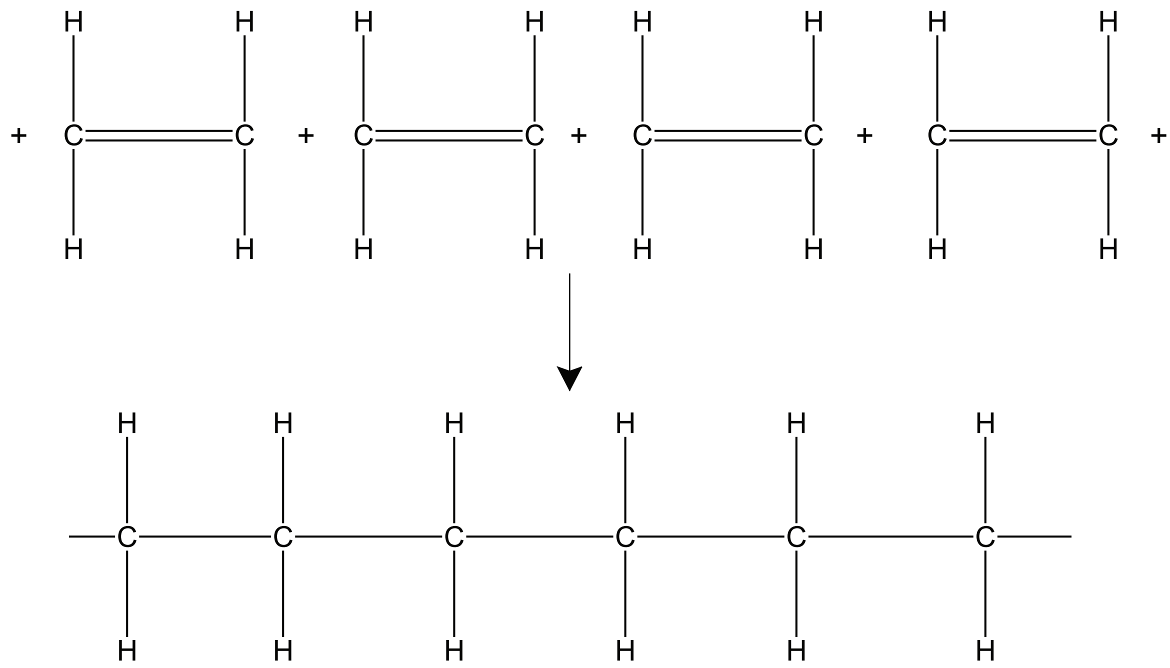
Plastics are made of polymers and are widely used in modern society. Polymer molecules are very long chains of identical molecules.

Polymers are made by joining together a **very** large number of small reactive molecules (monomers) to make a long chain.

The diagram represents what happens in the polymerisation process:

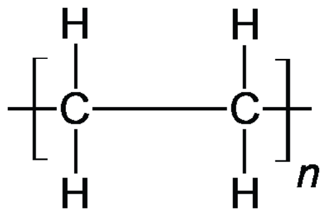


A diagram showing the formation of the polyethene from the monomer ethane is shown below.



Since the polymer chain is very long we use a simple way to sum up the polymer. This method shows the **repeat pattern** of the polymer.

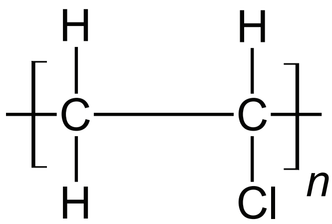
The repeat pattern of polyethene is written:



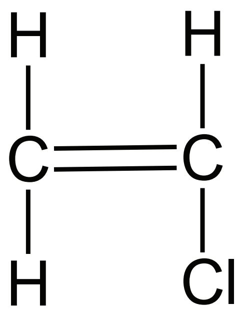
n is a very large number.

We can make other polymers with different repeat patterns. By changing the atoms in the repeat pattern we change the properties of the polymer.

An example is polyvinylchloride (PVC). The repeat pattern in PVC is:



This is made from a monomer containing one chlorine atom:



Plastics and the environment

Our use of plastics is growing. The amount of plastic manufactured in the first ten years of this century was close to the total produced in the entire last century. Plastics are very useful but there are consequences to their use. It has been said, that one of the most significant and long-lasting recent changes to the surface of our planet is the accumulation and fragmentation of plastics.

The problem with most plastics made from fossil fuels is that they remain in the environment for a very long time.

The environmental impacts of plastics include:

- litter problem - waste plastics are a visible and ugly component of litter.
- danger to wildlife - some animals mistake plastic for food. A great variety of animals, including marine animals, choke to death on plastics.
- plastic waste in the oceans - the amount of floating plastics in the world s oceans is growing dramatically. The 'Pacific Trash Vortex' is a large area of litter in the North Pacific Ocean. The vortex contains high concentrations of suspended plastics, such as plastic bags, bottles and containers that have been trapped by currents. It is now estimated to be twice the size of Texas.

Marine animals such as turtles or sea mammals can become tangled in this waste or may ingest it. Sometimes plastic that is ingested becomes stuck in their digestive system and the animal starves to death.

Remains of a young albatross and the plastic marine debris that filled this bird s digestive system and probably caused its death
Rosanne Tackaberry / Alamy Stock Photo

Bioplastics - another source of plastics

Most polymers are made from monomers obtained from cracking molecules obtained from crude oil. However we can use biomass as a source of molecules to produce polymers.

Bioplastics are plastics that are made from renewable biomass sources such as vegetable oils and corn starch.

The photo shows clear plastic pellets made from corn.

There are both advantages and disadvantages to using biomass as a source to produce polymers.

Corn-based plastic

Corn

Pascal Goetgheluck / Science Photo Library

Advantages	Disadvantages
Bioplastics come from a renewable source unlike oil-based plastics which come from non-renewable crude oil.	The land that is used for growing crops to produce oil for bioplastics is no longer available to grow food.
Less carbon dioxide (greenhouse gas) is released producing bioplastics than oil-based plastics.	Crops require the use of fertilisers and pesticides.
They are compostable: they decay into natural materials that blend harmlessly with soil.	

Bioplastics are also biodegradable. Some plastics made from crude oil are also biodegradable.

Biodegradable plastics are plastics that decompose by the action of living organisms, usually bacteria.

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

TEST YOURSELF

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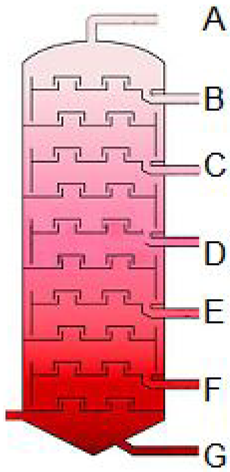
1. Name the process that is used to separate the mixtures in crude oil into fractions.

A crystallisation **B** distillation **C** refrigeration

2. Match the labels for each fraction in the diagram below.

A ………...
B …………
C …………
D …………
E …………
F ………….
G ………….



Resisue - bitumen
Kerosene - aircraft fuel
Gasoline (petrol)
Refinery ga
Diesel oil
Fuel oil
Naphtha

3. A bioplastic is:

A made from crude oil
B made from biomass
C not renewable

4. The 'Pacific Trash Vortex' is:

A a rich area of marine life
B an area of the pacific without any marine lif
C contains high concentrations of suspended plastics

How metal ores are processed

In order to understand how we chemically process a metal ore, we first need to understand some important chemical terms.

Oxidation and reduction - adding or removing oxygen

Reduction is the loss of oxygen from a substance.
Oxidation is the gain of oxygen by a substance.

Let us consider some examples.

When magnesium burns in air, it forms magnesium oxide.

Word equation: magnesium + oxygen → magnesium oxide
Symbol equation: $2Mg + O_2 \rightarrow 2MgO$

In the reaction, magnesium becomes chemically bonded to oxygen. **Magnesium** is therefore **oxidised.**

If we pass hydrogen gas over heated copper oxide, a chemical reaction occurs:

Word equation: copper oxide + hydrogen → copper + water
Symbol equation: $CuO + H_2 \rightarrow Cu + H_2O$

In this reaction the compound copper oxide loses oxygen to form copper. The **copper oxide** is **reduced.**

The movement of electrons

Oxidation and reduction can also be thought of in terms of electrons moving.

If we look at it this way then:

Oxidation is the loss of electrons **Reduction** is the gain of electrons

Memory device: Use **Oil Rig** to help remember oxidation and reduction.

We will only consider what happens when we chemically extract a metal from its ore.

All metal compounds contain positive metal ions. The metal ions need to **gain** electrons to form a metal.

Therefore metal ions must be **reduced** to obtain a metal from its ore.

For example

Molten aluminium oxide (Al_2O_3) contains both Al^{3+} ions and O^{2-} ions.

To change Al^{3+} ions in to Al atoms the aluminium ions need to **gain** electrons:

$Al^{3+} + 3^{e-} \rightarrow Al$

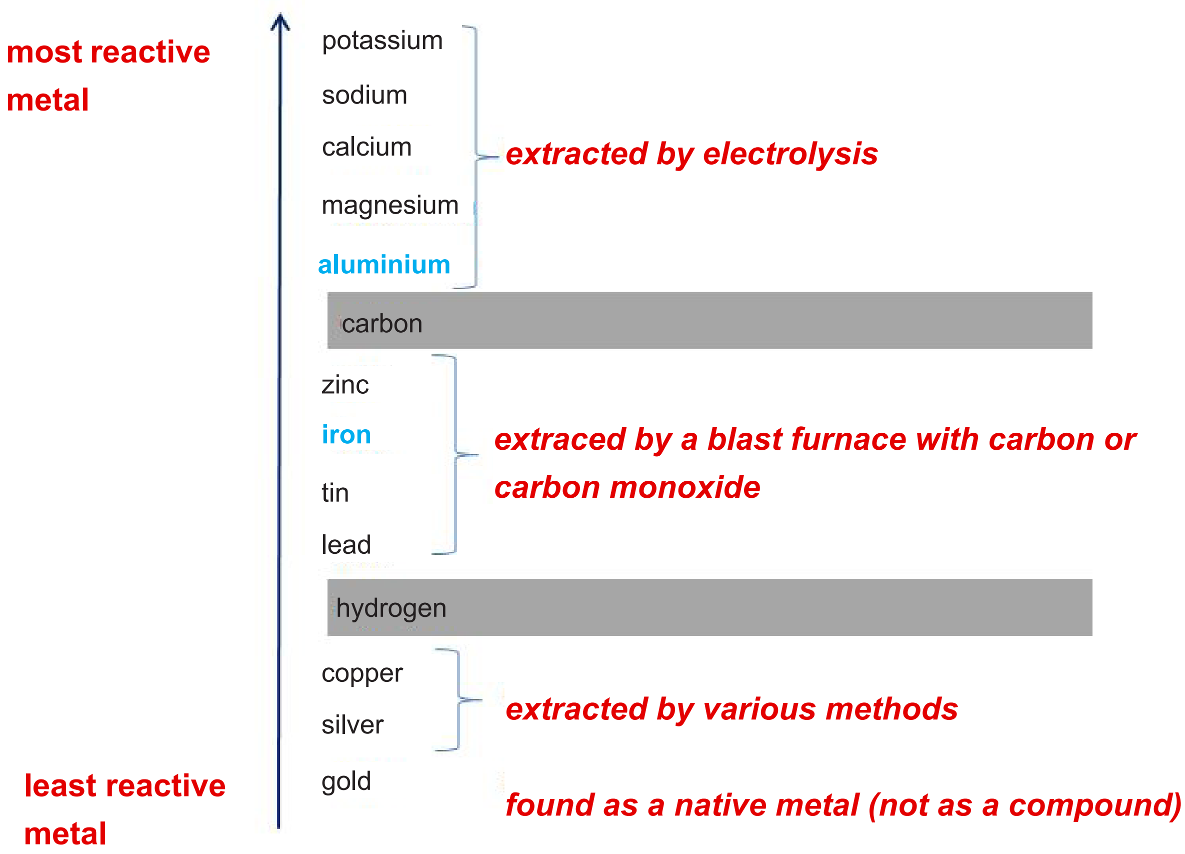
The aluminium ions (Al^3+) are **reduced** to aluminium (Al).

Reactivity of metals

Not all metals are equally reactive; some are more reactive than others.

Metals can be place in order of their reactivity, called the **reactivity series.**

The more reactive the metal the harder it is to extract from its ore. The most reactive metals need to be extracted using electricity. Metals which are less reactive than carbon can be extracted using carbon or carbon monoxide in a blast furnace.



You need to be able to recognise that the type of extraction method depends upon the position of the element in the reactivity series.

You are only required to know details of the extraction of aluminium and iron.

Reducing the ore

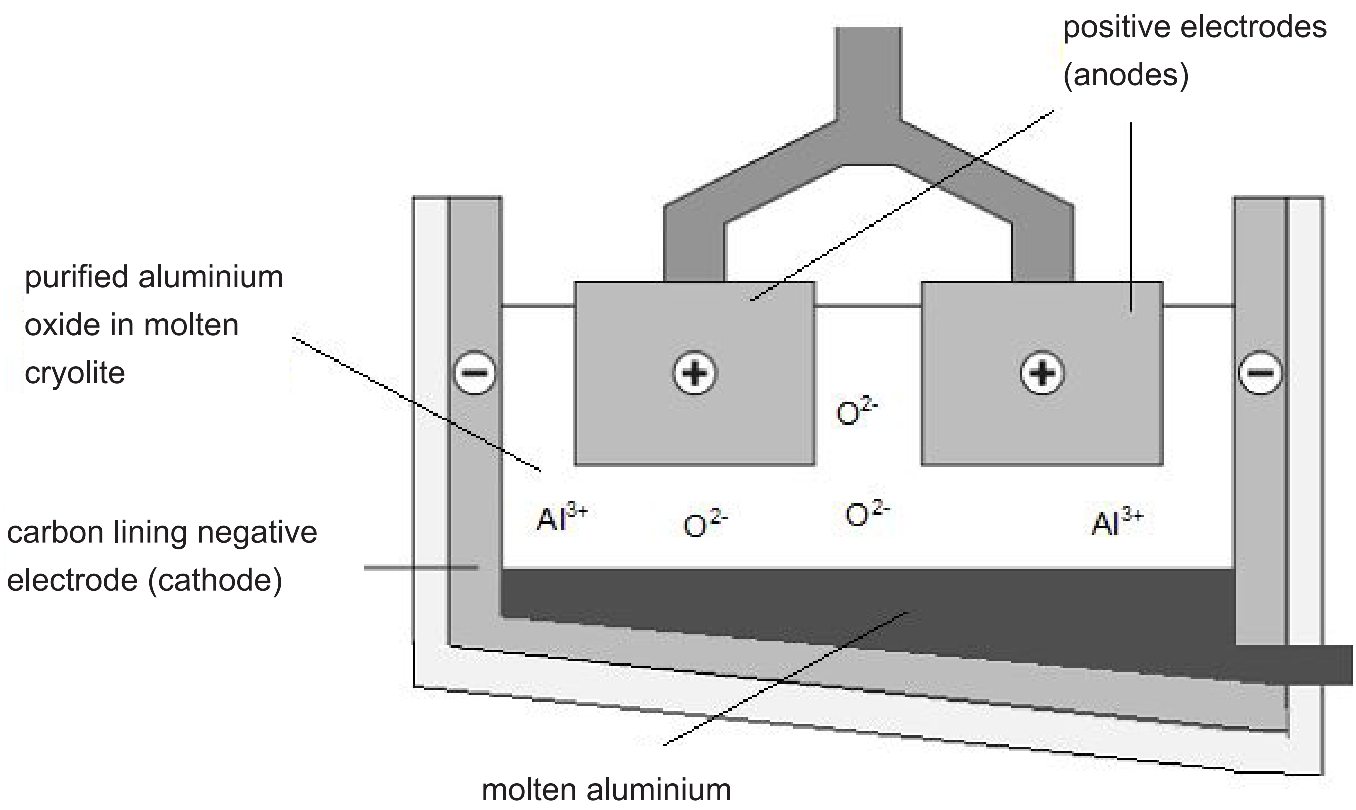
There is more than one way to reduce a metal ore. The method we use depends upon the reactivity of the metal. The more reactive the metal, the harder it is to reduce. Very reactive metals are extracted using electricity, while less reactive metals are extracted by reduction with carbon.

Extracting aluminium from its ore

Aluminium is a reactive metal which is extracted from an ore called **bauxite.**

Aluminium is too reactive to be extracted in a blast furnace so electricity must be used.

Electrolysis is used to extract this metal which uses electricity in the reduction process.



The aluminium oxide is dissolved in a substance called cryolite. Electricity is passed through the molten cryolite.

During electrolysis the positive aluminium ions (Al^{3+}) are attracted to the negative electrode. At the electrode the aluminium ions gain electrons (that means they are reduced).

The negative oxide ions (O^{2-}) are attracted to the positive electrode where they lose electrons to form oxygen gas.

Negative electrode:	$Al^{3+} + 3e^{-} \rightarrow$	Al	**Reduction** reaction
Positive electrode:	$2O^{2-} - 4e^{-} \rightarrow$	$2O_2$	**Oxidation** reaction

Extracting aluminium is expensive because lots of energy is needed in the process.

EXTENSION WORK

A compound which is made of ions it is called an **ionic** compound. Not all compounds are made of ions. However if you have a compound containing a metal it is almost certainly going to be an ionic compound.

In order for electrolysis to occur the ions must be able to move. Ions **cannot** move if the compound is a solid so you **cannot** carry out electrolysis on a solid compound. For the ions to move the compound must be either:

molten **OR** dissolved in water

Any compound which contains free moving ions, when molten or dissolved in solution, is called the electrolyte and can conduct an electrical current.

The positive ion will always be attracted to the negative electrode and the negative ion to the positive electrode.

Example

Lead bromide is a compound containing the metal lead. It is an ionic compound made of lead ions (Pb^{2+}) and bromide ions (Br^-) ions.

The following reactions will occur if we pass an electric current through molten lead bromide.

Negative electrode:	$Pb^{2+} + 2e^- \rightarrow$	Pb	**Reduction** reaction
Positive electrode:	$2Br^- - 2e^- \rightarrow$	Br_2	**Oxidation** reaction

Reduction reactions always occur at the negative electrode.

Extracting iron using a blast furnace

Less reactive metals are extracted using a blast furnace. Iron can be extracted from its ore this way.

In order to extract iron from its ore we need the following **raw materials:**

- iron ore (the main ore is haematite)
- coke (this contains carbon)
- limestone (this is used to remove impurities)
- air.

Haematite
Ben Johnson / Science Photo Library

Blast furnance Port Talbot
Robert Brook / Science Photo Library

The reactions in the blast furnace

Hot air is blasted into the furnace causing the coke (carbon) to burn, producing carbon dioxide and raising the temperature to **1 800°C.**

word equation: carbon + oxygen → carbon dioxide

symbol equation: $C(s) + O_2(g) \rightarrow CO_2(g)$

At very high temperatures in the blast furnace, the carbon dioxide then reacts with hot carbon to form **carbon monoxide.**

word equation: carbon dioxide + carbon → carbon monoxide

symbol equation: $CO_2(g) + C(s) \rightarrow 2CO(g)$

Carbon monoxide then **reduces** iron in the ore to iron metal.

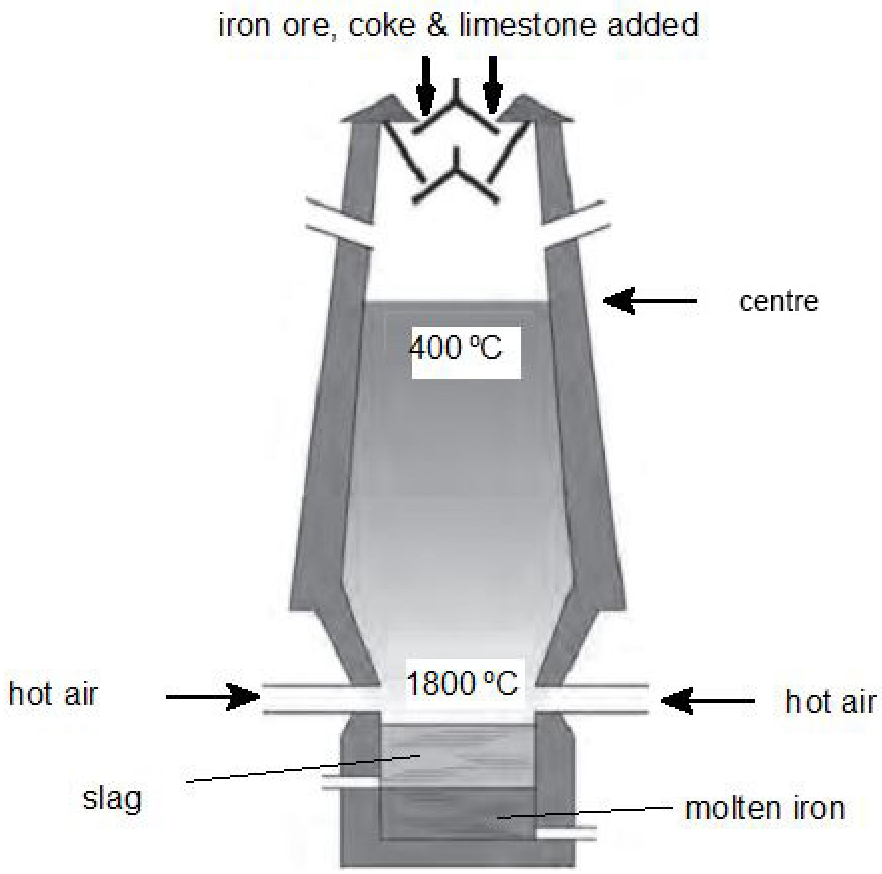
carbon monoxide + iron(III) oxide → carbon dioxide + iron

$3CO(g) + Fe_2O_3(s) \rightarrow 3CO_2(g) + 2Fe(l)$

Molten iron flows to the bottom of the furnace.

Molten iron is liquid at this temperature and is tapped off from time to time.

Limestone reacts with impurities in the iron to form slag which floats on top of the molten iron.



iron ore, coke & limestone added
centre
400 °C
1800 °C
hot air
hot air
slag
molten iron

Recycling metals v extracting metals from their ores

It takes less energy to melt and remould metals than it does to extract new metals from their ores. Aluminium is a valuable metal that melts at a relatively low temperature, and is particularly attractive for recycling.

Some advantages and disadvantages of recycling metals are shown in the table below.

Advantages	Disadvantages
Recycling helps to limit the amount of metals that must be produced. This will end with less rubbish in landfills because the metal is being reused. Slows the consumption of natural resources. The process of recycling metals usually creates (much) less pollutants and greenhouse gases than extracting the metal from its ore. Recycling uses less energy therefore less fossil fuels are being burnt.	The collection and sorting of domestic materials to be recycled can be expensive, time consuming and requires energy. It can be difficult to sort di ferent metals ready for recycling since many metals we use are alloys (mixtures of metals).

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

Recycled aluminium
Clynt Garnham Industry / Alamy Stock Photo

ELECTROPLATING

Electroplating is used to coat a cheap metal with a more expensive one, such as copper or silver.

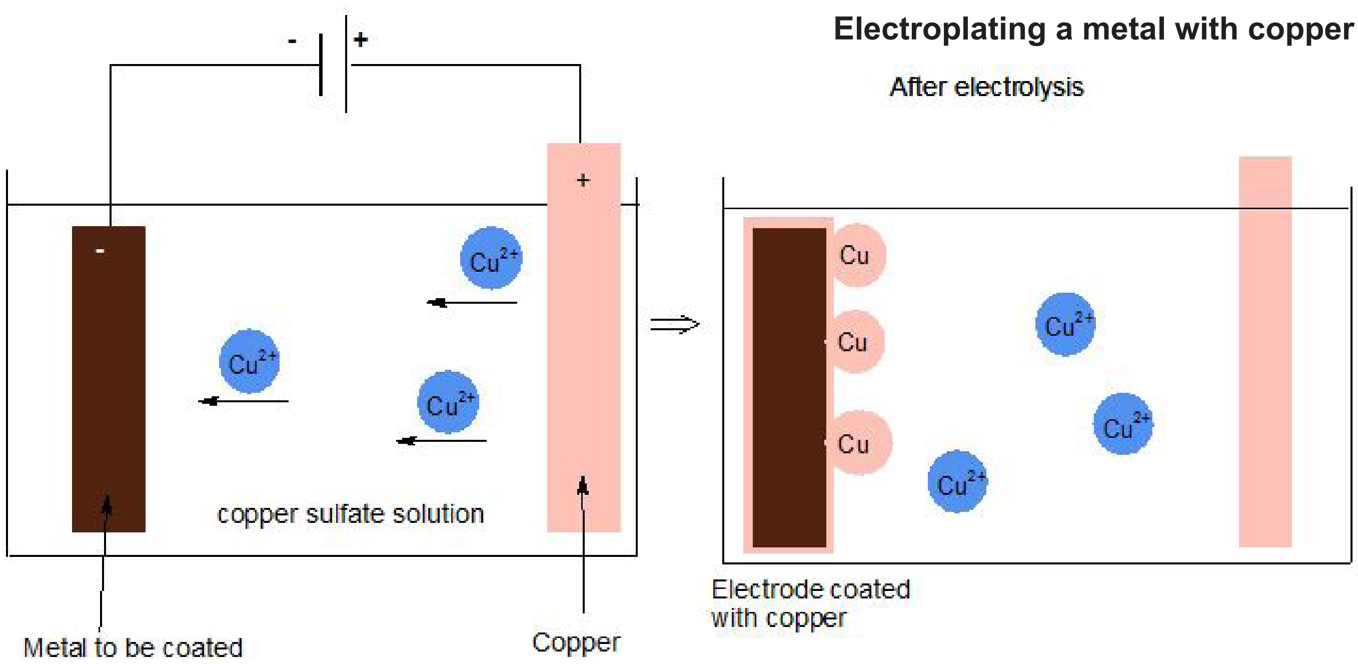
How electroplating works

Set up the apparatus as follows:

- the **negative electrode** is the object that needs to be electroplated
- the **positive electrode** is the metal that you want to coat the object with
- the **electrolyte** should be a solution of the coating metal, such as its metal sulfate or nitrate.

For example, if we want to electroplate a metal with copper, we make:

- the negative electrode the metal to be coated
- the positive electrode copper
- use copper sulfate as the electroloyte.



Obtaining resources from our planet (Unit 1.2)

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SOMETHING TO WATCH

Watch a video explaining electrolysis:

https://youtu.be/U9Y8xclePOw

Published on 21 Apr 2012 Category Education Licence Standard YouTube Licence

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Why electroplate metals?

Electroplating is generally done for different reasons, e.g.

1. for decoration
2. to provide corrosion resistance
3. to reduce abrasive wear.

Necklace
Berkut_34 / gettyimages

Examples

1. Making cheap jewellery:

   We can make cheap jewellery by coating silver or gold onto the surface of a cheap metal. Much cheaper than using solid silver or gold!

2. Zinc plating (galvanising):

   Metals may also be coated to make them more resistant to corrosion.

   Many everyday items made from iron are plated with zinc to protect them from corrosion.

Nails
Phil Degginger / Science Photo Library

3 Chromate plating:

This gives a surface which is resistant to corrosion, gives ‘wear resistance’ and looks good.

Tap
TEK Image / Science Photo Library

Metal corrosion

Most metals rust when they are exposed to the open air and bad weather. Chemists call rusting corrosion.

Metals react with oxygen to form a metal oxide during corrosion.

Example

iron + oxygen → iron(III) oxide
$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Since the metal gains oxygen in this process, we call this an oxidation reaction. This is the reverse reaction of the extraction of iron from its ore.

Rusting wreck of the S.S. Peter Iredale
Tom Myers / Science Photo Library

Obtaining resources from our planet (Unit 1.2)

Resources from our planet (specification 1.2.2)

TEST YOURSELF

---

1. An electric current is passed through molten lead bromide. At one electrode the following change takes place:

$Pb^{2+} + 2e^{-} \rightarrow Pb(l)$

Lead formed at the (**positive / negative**) electrode.
This reaction is an example of a (**reduction / oxidation**) process.

2. The following are the raw materials needed to produce iron:

A bauxite, coke, limestone and air
B haematite, bauxite, coke and limestone
C haematite, coke, limestone and air

3. Balance the following reaction for the equation of iron(III) oxide in the blast furnace:

$.....CO(g) \;+\; Fe_2O_3(s) \;\rightarrow\; .....CO_2(g) \;+\; .....Fe(l)$

The missing numbers from the equation (in order) are:

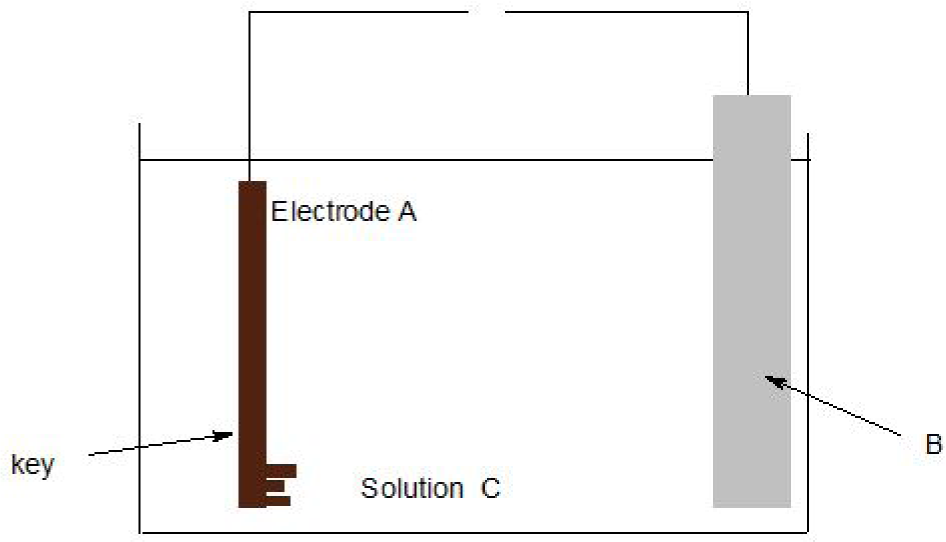
A 1, 1, 2
B 2, 2, 2
C 3, 3, 2

4. Complete the following sentences by underlining the correct word in the brackets.
Aluminium is extracted from its ore using
(**electroplating / electrolysis / electrophoresis**).

In this process the aluminium ions (**A^{l+} / Al^{2+} / Al^{3+}**) are
(**reduced / oxidised / decomposed**).

TEST YOURSELF

5. A steel key needs to be electroplated with zinc. The apparatus is shown in the diagram below.



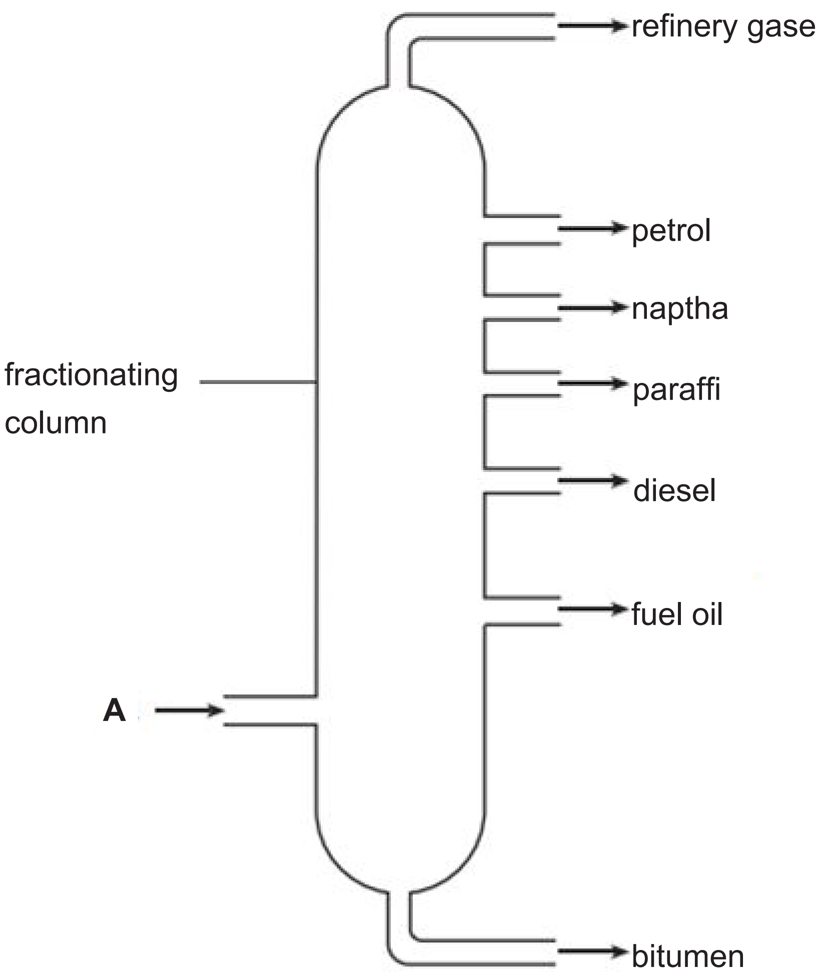
There is a (**positive / negative**) charge on the electrode A.

Electrode B is made of (**iron / zinc / copper**).

Solution C is (**iron(II) sulfate / zinc(II) sulfate / sodium sulfate**).

PRACTICE QUESTIONS

1. **(a)** Crude oil is a mixture of compounds called hydrocarbons which can be separated into fractions in a fractionating column as shown below.



(i) Name the elements present in all hydrocarbons. [1]

.... and

....

(ii) State what must happen:

I. to the crude oil before it enters the column at point A. [1]

....

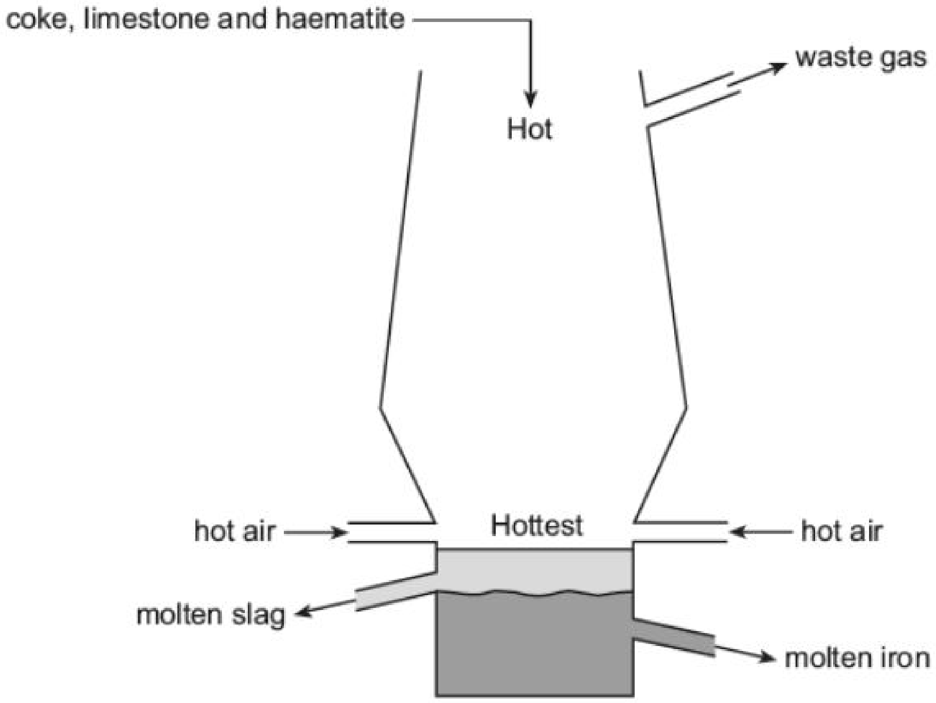
II. in order to collect the fractions as liquids. [1]

....

(iii) Give the name of this process. [1]

....

2. The diagram below shows the blast furnace which is used to extract iron.



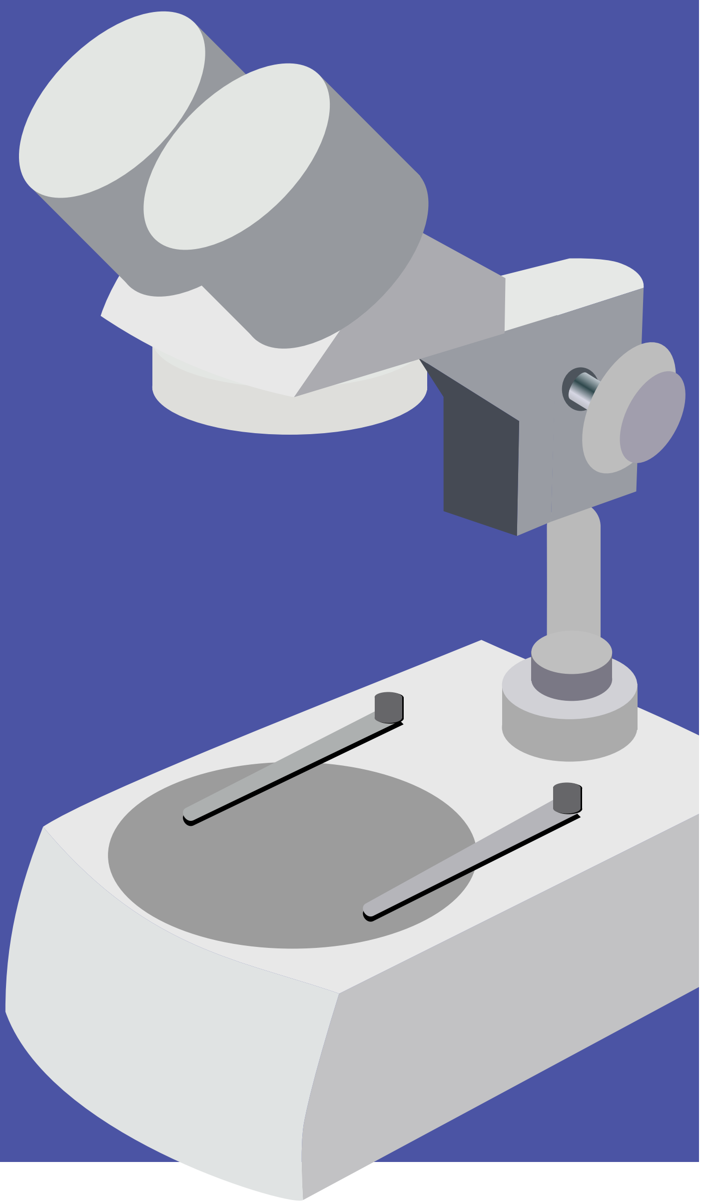
The table shows some information about the raw materials used in the process.

Complete the table. [3]

Raw material	Chemical name	Symbol or formula	Type of material
haematite	…………………..	Fe_2O_3	compound
coke	carbon	C	………………..
limestone	calcium carbonate	……………….	compound

Obtaining resources from our planet (Unit 1.2)

Producing useful compounds in the laboratory (specification 1.2.3)



SOME IMPORTANT TERMS

Acid, base and alkali

An acid is a substance which has a pH below 7.

Some important acids are:

- hydrochloric acid (HCl)
- sulfuric acid (H_2SO_4)
- nitric acid (HNO_3).

A base is the chemical opposite of an acid. A base has a pH which is greater than 7.

A base can react with an acid in a neutralisation reaction. Metal oxides and metal hydroxides are usually bases. Ammonia is also a base. Some important bases are:

- ammonia
- sodium hydroxide
- copper oxide.

Most bases do **not** dissolve in water but some do.

An alkali is a base that dissolves in water.

Ammonia and sodium hydroxide dissolve in water and are therefore alkalis. Copper oxide does not dissolve in water. It is not an alkali.

Obtaining resources from our planet (Unit 1.2)

Producing useful compounds in the laboratory (specification 1.2.3)

SOME IMPORTANT TERMS

The pH scale

It is possible to tell if a solution is acidic, neutral or alkaline by using an indicator.

An indicator is a substance which has different colours in acidic or alkaline solutions.

Litmus, phenolphthalein and methyl orange are examples of indicators.

Litmus is red in acids and blue in alkalis.

Solutions of acids and alkalis can vary widely in their acidity and alkalinity. It is useful to know not just whether a solution is an acid or an alkali, but **how** acidic or how alkaline it is.

Acidity and alkalinity are measured using the **pH scale.**

The easiest way to do this is to use **universal indicator.**

A neutral solution has a pH of 7. An acidic solution will have a pH below 7 while an alkaline solution will have a pH above 7.

Universal indicator (UI) is a mixture of several different indicators. The colour of the universal indicator shows the pH value of the solution. The pH scale runs from pH 0 to pH 14.

colour UI	Red	Orange	Yellow	Green	Blue	Navy	Purple
pH range	0 - 2	3 - 4	5 - 6	7 - 8	9 -10	11 - 12	13 - 14

← Increasingly acidic | **neutral** (7) | increasingly alkaline →

SALTS

An important group of compounds are known as salts.

A salt is formed whenever an acid reacts with a metal, base (metal oxide, metal hydroxide or ammonia) or a metal carbonate.

A salt is made of a positive ion (metal ion or ammonium ion [NH_4^+]) and negative ion which comes from an acid (e.g. chloride, nitrate or sulfate).

Uses of salts

Salts have many important uses. Some examples of uses of salts are given below. You do not need to remember these for an exam. They are given to illustrate the usefulness of salts.

- Both ammonium nitrate and potassium nitrate are used as artificial fertilisers.
- Zinc sulfate is used to supply zinc in animal feeds, fertilizers, and agricultural sprays. Zinc sulfate can also be used to control moss growth on roofs.
- Copper sulfate can be used in the garden as a fungicide (a compound that kills or slows the growth of fungi).

Fertiliser
lee avison / Alamy Stock Photo

- Iron(II) sulfate is used to green up grass in a garden without causing too much growth.

- Magnesium sulfate can be used orally as a laxative to relieve constipation, and to treat low levels of magnesium.

- Calcium sulfate $CaSO_4$ (calcium sulfate) is used in plaster of Paris.

Plaster of Paris
Alamy Stock Photo

MAKING SALTS

Reactions that we can use to make salts are summarised over the next few pages.

Method 1: Acids with metals

Acids will react with **reactive** metals, such as magnesium and zinc, to form a salt **and hydrogen.** In general:

metal + acid → **salt** + hydrogen

The hydrogen causes bubbling during the reaction, and can be detected using a lighted splint.

Example:

Zinc metal reacts with sulfuric acid to form zinc sulfate ($ZnSO_4$) and hydrogen.

Word equation	zinc + sulfuric acid → zinc sulfate + water
Symbol equation	$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

Copper, and metals below it in the reactive series, are **not** reactive enough to react with acids.

Method 2: Acids with bases

Acids react with bases to form a salt and water. This reaction is called **neutralisation.**

In general:

acid + metal oxide → **salt** + water

If a base can dissolve in water, it is also called an alkali.

Example:

Sulfuric acid reacts with copper oxide.

Word equation copper oxide + sulfuric acid → copper sulfate + water

Symbol equation $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$

Ammonia is also an alkali that reacts with acids in a neutralisation reaction. A general equation for the reaction of ammonia is:

acid + ammonia → **salt**

Example:

Ammonia reacts with nitric acid.

Word equation ammonia + nitric acid → ammonium nitrate

Symbol equation $NH_3 + HNO_3 \rightarrow NH_4NO_3$

Method 3: Acids with carbonates

When acids react with carbonates, such as calcium carbonate, a salt, water and carbon dioxide are made.

In general:

acid + metal carbonate → **salt** + water + carbon dioxide

The carbon dioxide causes bubbling during the reaction, and can be detected using limewater.

Example

Sulfuric acid reacts with calcium carbonate.

Word equation copper carbonate + sulfuric acid → copper sulfate + carbon dioxide + water

Symbol equation $CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + CO_2 + H_2O$

Choosing the acid to make a salt

The type of salt you need tells you the acid you need to make it:

- nitric acid gives nitrates
- hydrochloric acid gives chlorides
- sulfuric acid gives sulfates.

Method 4: Precipitation reactions

Soluble salts dissolve in water. Insoluble salts do not dissolve in water.

An insoluble salt can be made by mixing together two soluble salts. This is known as a **precipitation reaction.**

Example

Calcium carbonate is an insoluble salt.

We can make this from two soluble salts.

- one of the soluble salts will need to have a **calcium ion** e.g. calcium nitrate
- the other a **carbonate ion** e.g. sodium carbonate

If we mix solutions of these two salts, the **in**soluble **calcium carbonate** will be formed.

Word equation:

calcium nitrate(aq) + sodium **carbonate**(aq) → **calcium carbonate(s)** + sodium nitrate(aq)

Obtaining resources from our planet (Unit 1.2)

Producing useful compounds in the laboratory (specification 1.2.3)

Some important names and formulae

The following table summarises some important formulae you must know. This will help you when you write equations for reactions to make salts.

Name	Formula	Name	Formula
hydrochloric acid	HCl	hydrogen	H_2
sulfuric acid	H_2SO_4	carbon dioxide	CO_2
nitric acid	HNO_3	water	H_2O
ammonia	NH_3		

Some important salts

You should be able to use the formulae of ions to work out the formula of salts.

You can test yourself. See if you can work out the formula of salts and check your answer from the table below.

Name	Formula	Name	Formula
sodium chloride	$NaCl$	calcium nitrate	$Ca(NO_3)_2$
potassium chloride	KCl	copper nitrate	$Cu(NO_3)_2$
ammonium chloride	NH_4Cl	zinc nitrate	$Zn(NO_3)_2$
magnesium chloride	$MgCl_2$	sodium sulfate	Na_2SO_4
calcium chloride	$CaCl_2$	potassium sulfate	K_2SO_4
copper chloride	$CuCl_2$	ammonium sulfate	$(NH_4)_2SO_4$
zinc chloride	$ZnCl_2$	magnesium sulfate	$MgSO_4$
sodium nitrate	$NaNO_3$	calcium sulfate	$CaSO_4$
ammonium nitrate	NH_4NO_3	zinc sulfate	$ZnSO_4$
magnesium nitrate	$Mg(NO_3)_2$		

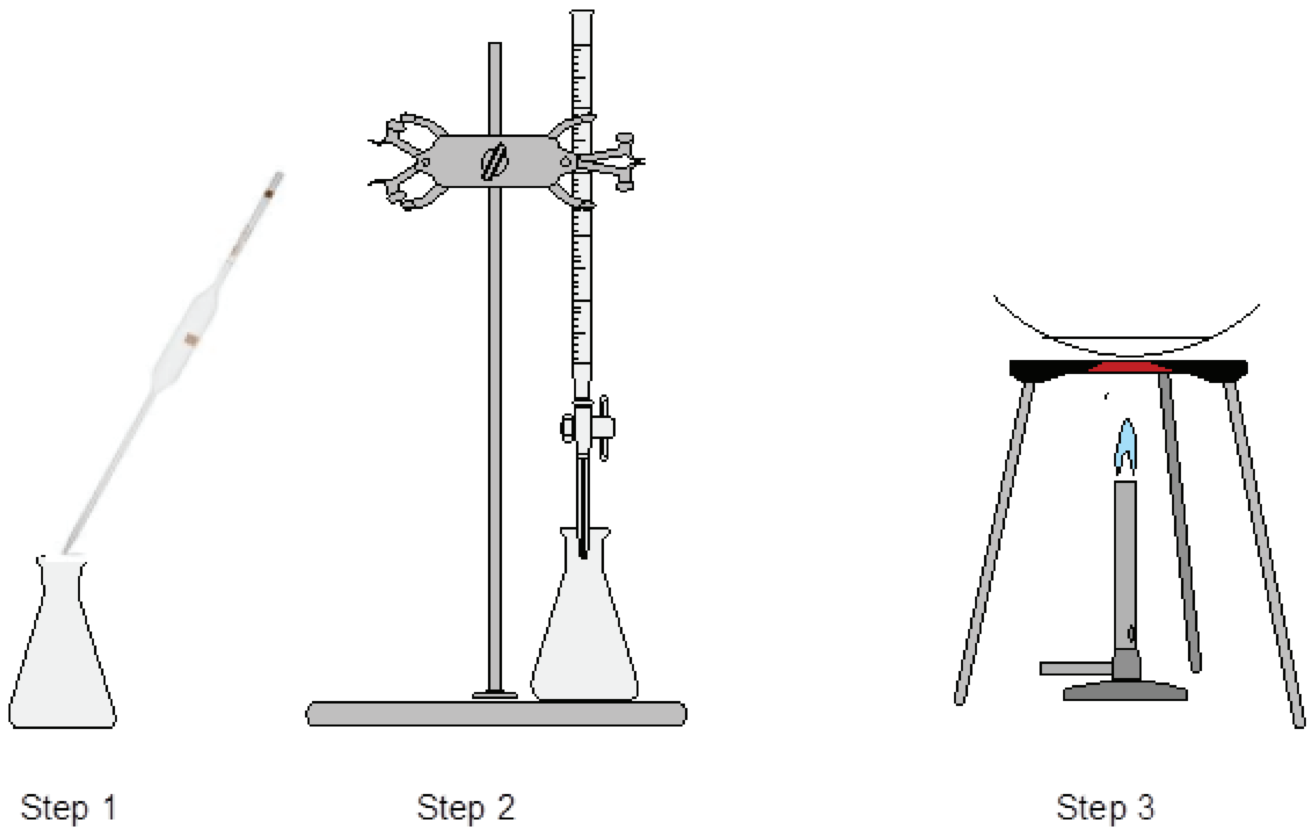
LABORATORY PROCEDURES TO MAKE SALTS

We have seen the chemical reactions that can be used to make a salt but how do we do it in the laboratory, and if there is more than one way, which is best?

Making a soluble salt

Method A: Neutralising an alkali (soluble base) with an acid

We need to know the exact amount of acid to just completely neutralise the alkali.



1. A known volume of acid is pipetted into a conical flask and a few drops of indicator added.

2. The acid is titrated with the alkali from the burette. The acid is added until the indicator changes colour. This means all the acid has been neutralised to form the salt.
   The volume of alkali needed for neutralisation is noted (this is the endpoint).

3. Steps (1) - (2) are repeated with exactly the same volume of alkali added from the burette but without the indicator.

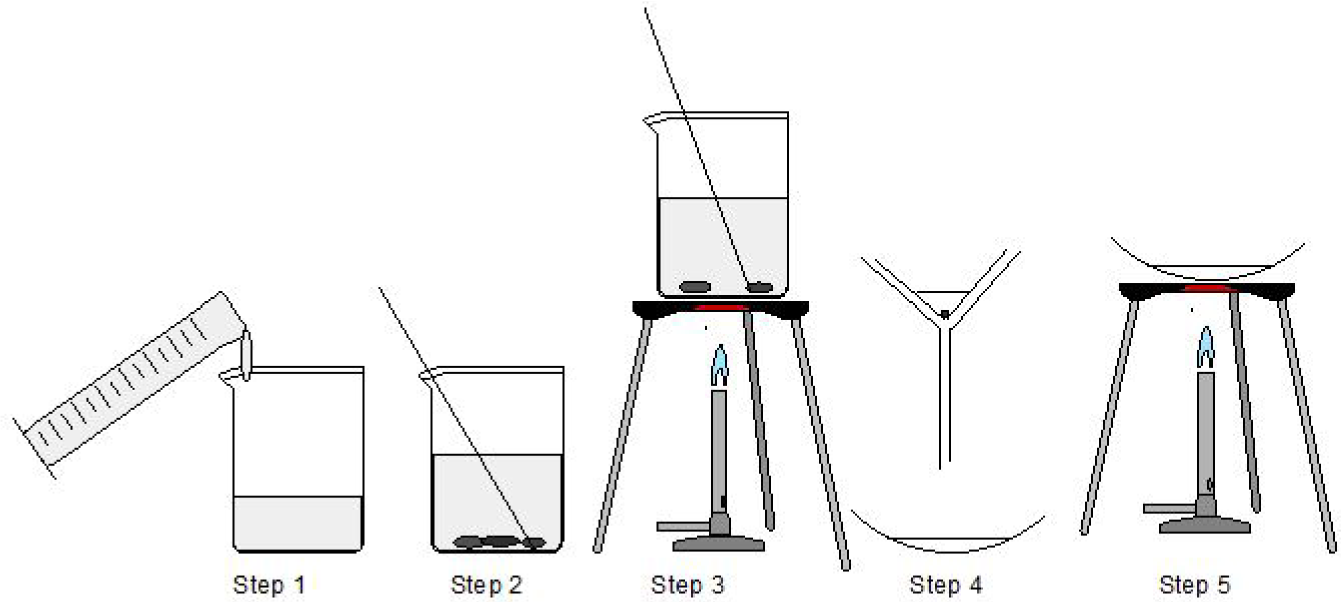
4. The solution is transferred to an evaporating dish and heated to evaporate some of the water causing crystallisation or can be left to very slowly evaporate - which tends to give bigger crystals.

5. The crystals can be collected by filtration and dried.

Obtaining resources from our planet (Unit 1.2)

Producing useful compounds in the laboratory (specification 1.2.3)

Method B: Reacting an acid with a metal or with an insoluble base to give a soluble salt



1) Measure out the required volume of acid into a beaker using a measuring cylinder.

2) Weigh out an excess amount of insoluble metal, oxide, hydroxide or carbonate and add in small portions to the acid in the beaker with stirring.

3) The mixture can be heated to speed up the reaction. Keep adding solid until no more dissolves. All the acid is now neutralised. You should see some of the solid (oxide, hydroxide, carbonate) left at the bottom of the beaker.

4) Filter the solution to remove the excess solid.

5) Heat the solution to remove some water. Now leave the hot solution to cool and crystallise. After crystallisation, collect and dry the crystals with a filter paper.

Important note on the reactions between acids and metals

An acid reacting with a metal does not always work.

Metals that can be used include magnesium, iron and zinc.

Copper is an example of a metal that will **not** react with dilute acids.

Group 1 metals react explosively with acids so this would **not** be a sensible method to prepare salts of group 1.

Method C: Precipitation reaction

1) Two solutions of soluble substances are mixed together in a beaker.
2) The precipitate is filtered off.
3) The precipitate is washed with deionised water.
4) The precipitate is scraped off the filter paper and dried in an oven.

Deciding on the best method to prepare a salt

There may be more than one way of preparing a salt. If this is the case you may need to decide on the best method to use. How can you make a decision on which is best?

Think about the following:

Safety

Are there any safety issues with a method?

All other things being equal, choose the method which gives the lowest risk to the safety of the people doing the work.

Examples of hazards

- Acids and alkalis may be hazardous especially if splashed into the eye
- Heating with a naked flame may increase the risk of a burn
- Any hydrogen gas produced is flammable

Skills required

What skills are required? Is one method much easier to do than another method?

Example of skill levels

- A titration requires a higher level of skill than the other procedures described.

How much time

How long does each procedure take? Is one procedure much quicker than the others?

Success of the methods

This can be judged by your yield. How much salt did you get? Which method gave the best yield of product?

Yield can be measured using:

$$\text{yield} = \frac{\text{actual amount obtained}}{\text{expected amount}} \times 100$$

Obtaining resources from our planet (Unit 1.2)

Producing useful compounds in the laboratory (specification 1.2.3)

TEST YOURSELF

1. Underline the correct words in the brackets to complete the following sentences.

A neutral solution has a pH of (**5 / 6 / 7 / 8**).
A solution with a pH of 4 is (**acidic / alkaline**). A solution with a pH of 2 is (**more / acidic / more / alkaline**) than a solution with pH of 4.

2. The word equation below for the reaction of zinc and nitric acid is:

A zinc + nitric acid → zinc nitrite + hydrogen
B zinc + nitric acid → zinc nitrite + water
C zinc + nitric acid → zinc nitrate + water
D zinc + nitric acid → zinc nitrate + hydrogen

3. The word equation for the reaction between magnesium carbonate and sulfuric acid is:

A magnesium carbonate + sulfuric acid → magnesium sulfite + water + hydrogen
B magnesium carbonate + sulfuric acid → magnesium sulfate + hydrogen + carbon dioxide
C magnesium carbonate + sulfuric acid → magnesium sulfite + water + carbon dioxid
D magnesium carbonate + sulfuric acid → magnesium sulfate + water + carbon dioxide

4. Balance the equation between sodium carbonate and lead nitrate by adding the correct number to the box

$Na_2CO_3(aq) + Pb(NO_3)_2 \rightarrow PbCO_3(s) + \square\ NaNO_3(aq)$

The number is: **A** 1 **B** 2 **C** 3

5. Copper sulfate is a soluble salt. Which method **cannot** be used to make copper sulfate?

- **A** Copper and dilute sulfuric acid
- **B** Copper oxide and dilute sulfuric acid
- **C** Copper carbonate and dilute sulfuric acid

6. Silver chloride is an insoluble salt.

Salt	Soluble? (yes/no)
silver sulfate	no
silver nitrate	yes
sodium chloride	yes
sodium carbonate	yes

Look at the information in the table and decide two salts that could be used to make silver chloride.

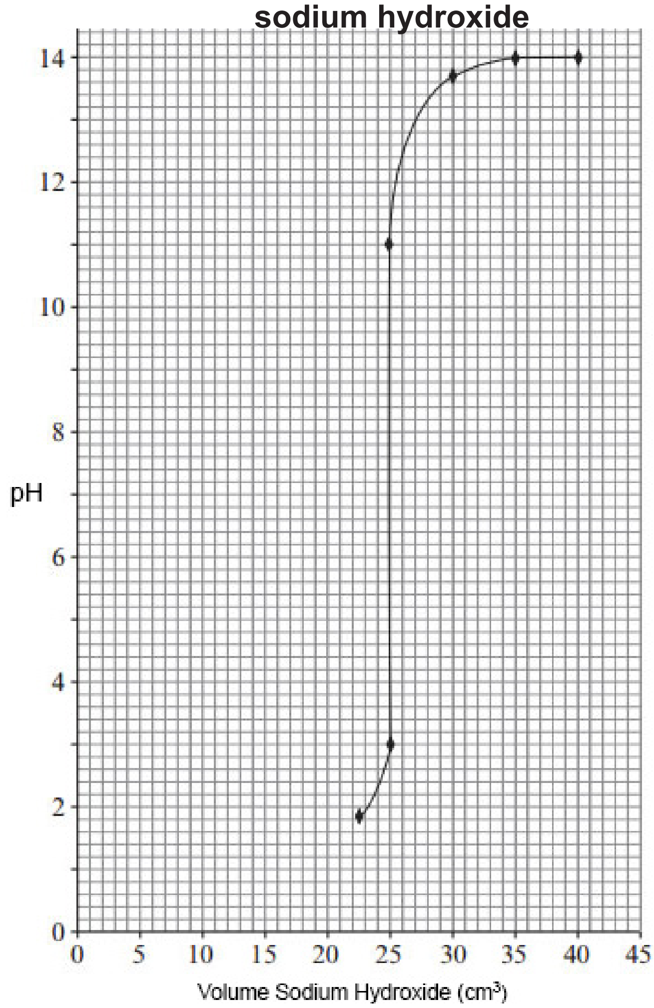
- **A** silver nitrate and sodium carbonate
- **B** silver sulfate and sodium chloride
- **C** silver nitrate and sodium chloride

PRACTICE QUESTIONS

1. David is investigating the neutralisation reaction between hydrochloric acid and sodium hydroxide. He measured the pH as he added sodium hydroxide solution to dilute hydrochloric acid from a burette. He has started to plot his results in a graph.

Volume of sodium hydroxide (cm^3)	pH readings
0	1.0
5	1.0
10	1.1
15	1.2
20	1.5

David's graph showing pH against volume of sodium hydroxide



(a) **(i)** Complete the graph. **[3]**

(ii) Use the graph to find the volume of sodium hydroxide solution required to neutralise the dilute hydrochloric acid. **[1]**

.... cm^3

(b) Give the chemical formula of the salt formed when David reacted hydrochloric acid with sodium hydroxide. **[1]**

....

(c) Acids and alkalis react to form a salt and water.

In this experiment David followed the method below.

Method:

1. Pipette 25 cm^3 of dilute acid into a conical flask
2. Add a few drops of universal indicator.
3. Add 40 cm^3 of sodium hydroxide solution to a burette.
4. Add 2 cm^3 of sodium hydroxide solution to the dilute acid from the burette.
5. Record the pH using a colour chart.
6. Repeat steps 4 and 5 until all the sodium hydroxide solution is added.

Suggest three changes to this method which will allow David to make a pure salt. **[3]**

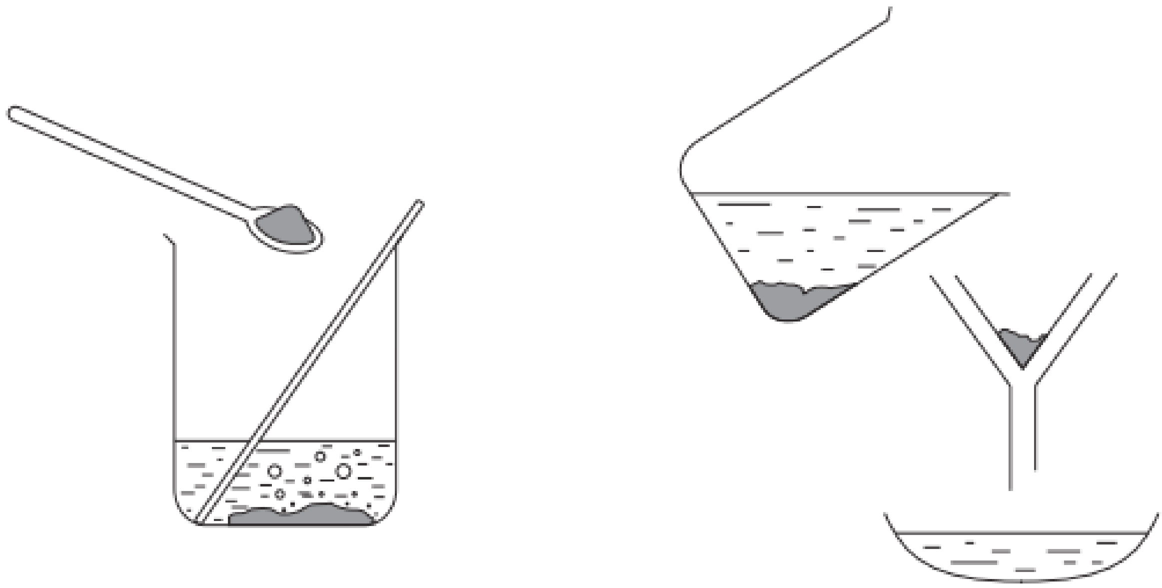
....

....

....

....

2. Copper sulfate crystals can be prepared by reacting copper carbonate with dilute sulfuric acid. The unlabelled diagrams below show two of the three stages involved.



Describe the preparation of copper sulfate crystals by this method. **[6 QER]**
Include in your answer what you would expect to see at each stage.

....

....

....

....

....

....

....

....

TEST YOURSELF - ANSWERS FOR UNIT 1.2

Elements

1. a) C
b) C
c) B
d) A
e) B
f) A
g) A
h) C

2. a) C
b) B

Compounds

1. E
2. E
3. A

TEST YOURSELF - ANSWERS FOR UNIT 1.2

Atomic structure

Symbol	Mass number	Atomic number	Number of protons	Number of neutrons	Number of electrons
$^{13}_{6}C$	13	6	6	7	6
$^{35}_{17}Cl$	***35***	***17***	***17***	***18***	***17***
$^{24}_{12}Mg$	24	***12***	12	***12***	***12***
$^{14}_{7}N$	***14***	7	***7***	7	***7***

Electronic Structure

1. A
2. B
3. B
4. C

Ions and atoms

1. C
2. A
3. A
4. B
5. C

Working out the formula of simple compounds

1.

Metal ion name	Charge on metal ion	Formula of ion	Negative ion name	Charge on negative ion	Formula of ion
sodium	***+1***	Na^+	bromide	-1	Br^-
calcium	+2	Ca^{2+}	***chloride***	-1	Cl^-
magnesium	+2	***Mg^{2+}***	sulfate	***-2***	SO_4^{2-}

2. C
3. B

Water in our environment

1. C
2. C
3. A
4. small particles, kills microorganisms, Chlorine

Desalination

1. near, cheap

Solubility curves

1. B
2. C
3. A
4. C

The structure of the earth

1. 20%
2. Carbon dioxide, ammonia, water vapour
3. Carbon dioxide, oxygen

The Periodic Table

1. explosively
2. (a) C, (b) B
3. C

Chemical reactions

1. C
2. B
3. B
4. C

Obtaining raw materials

1. A
2. C
3. B

Processing crude oil

1. B
2. A – refinery gas B – gasoline (petrol) C – Naphtha
   D - kerosene-aircraft fuel E – diesel oil F – Fuel oil G – Residue-bitumen
3. B
4. C

How metal ores are processed

1. negative reduction
2. C
3. C
4. electrolysis, Al^{3+}, reduced
5. negative, zinc, zinc(II) sulfate

Producing useful compounds in the laboratory

1. 7, acidic, more acidic
2. D
3. D
4. B
5. A
6. C

Science in the Modern World (Unit 1)

Our planet (Unit 1.3)

Our place in the Universe (specification 1.3.1)

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

USING ELECTROMAGNETIC RADIATION TO EXPLORE THE UNIVERSE

Planet Earth is just one body that orbits a star that we know as the Sun. The Sun is just one of a very large number of stars that make up our galaxy. There are estimated to be between 100 and 400 billion stars in the galaxy that contains our own solar system, the Milky Way.

View of Milky Way in Chile
Jesse Kraft / Alamy Stock Photo

These stars are very far away and can only be examined by powerful telescopes using the electromagnetic radiation emitted from them. Although space probes have landed on the surfaces of planets in our own solar system, much of the information comes from examining electromagnetic radiation reflected from the planet s surface.

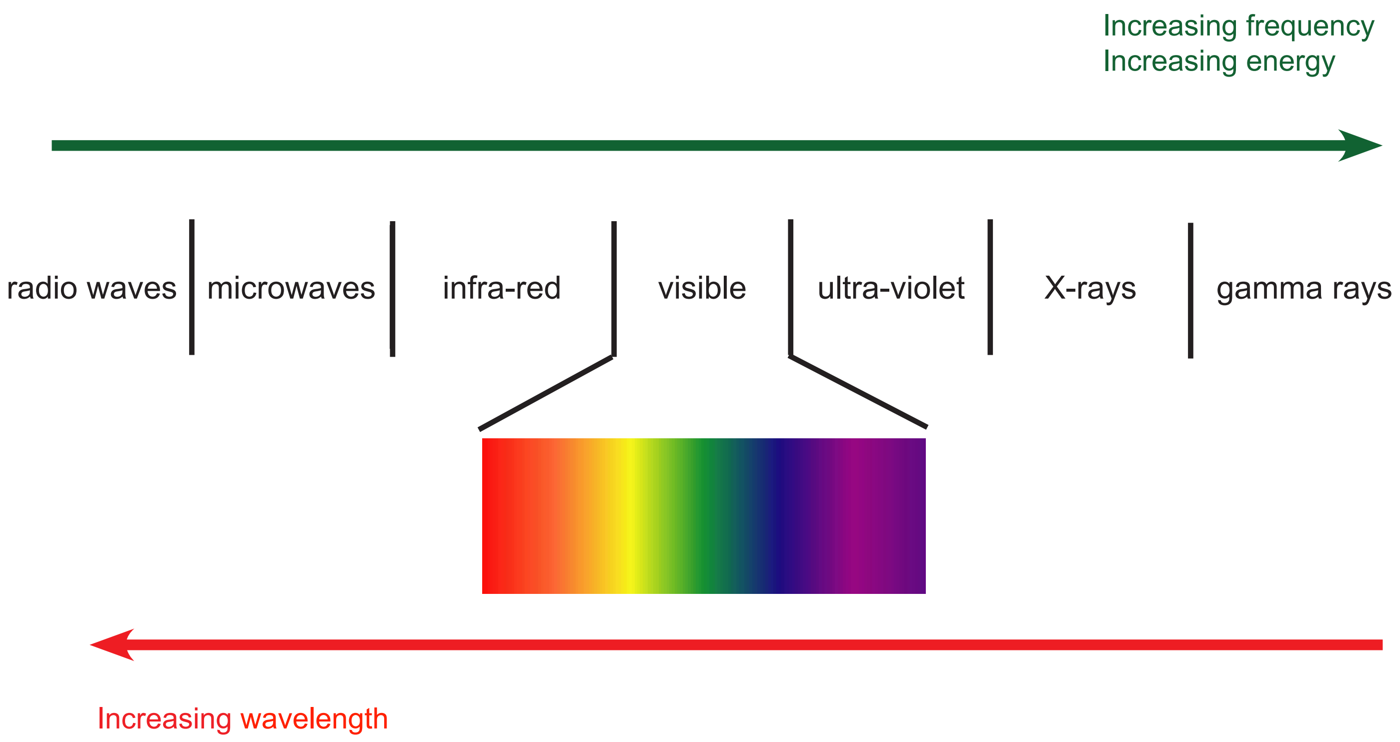
Electromagnetic radiation

Light is a small part of the electromagnetic spectrum which our eyes are able to detect. Light has certain things in common with all other electromagnetic radiation. All forms of electromagnetic radiation:

- travel at the same speed in a vacuum – 'the speed of light'
- are transverse waves
- can be reflected, refracted and diffracted.

The main parts of the electromagnetic spectrum are shown in the diagram (not drawn to scale) below:

Make sure you know the order of the different parts of the electromagnetic spectrum in terms of frequency, energy and wavelength



Notice: The greater the frequency or shorter the wavelength, the more energy.

Speed, wavelength and frequency

Speed

In a vacuum all electromagnetic radiation travels at the same speed, ‘the speed of light’.

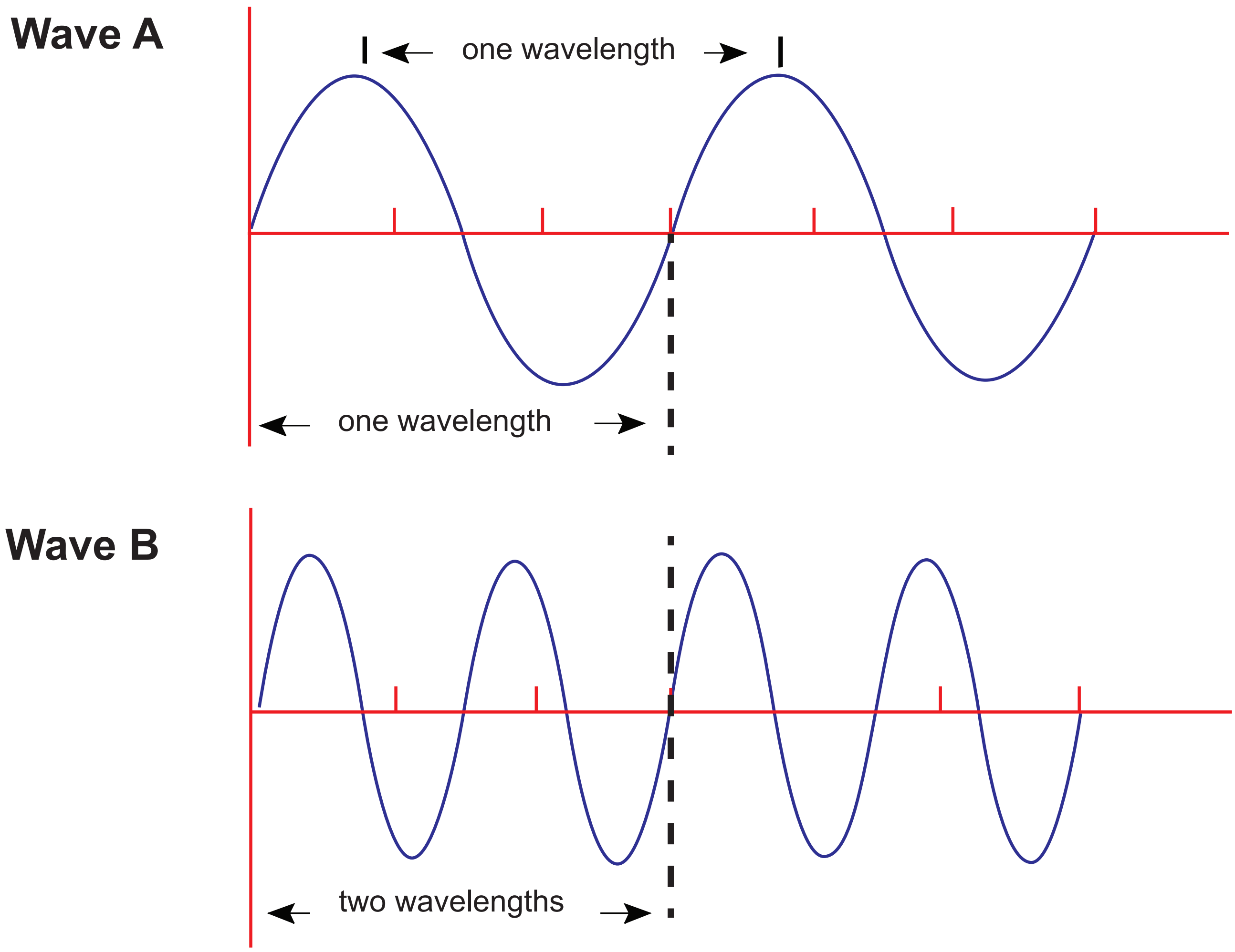
The speed of light is 3 × 108 m/s. That is 300 000 000 m/s

At this speed you could travel around the world 7.5 times in one second!

Runner
Afiat Sukmaraga / gettyimage

Wavelength

The wavelength of a wave is the distance between a point on one wave and the same point on the next wave. The diagram below shows two waves with different wavelengths.



Notice **Wave A** has a wavelength which is twice that of **Wave B**.

Wavelength may be measured in units of metres or parts of a metre (e.g. nanometre, nm).

1 nm = 0.000000001 m = 1×10^{-9} m.

That is 1 millionth of millimetre.
A magnifying glass will not help!

Magnifying glass
Zoonar RF / gettyimages

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Frequency

The frequency of a wave is the number of waves that pass a certain point each second.
The unit of frequency is the hertz (Hz).

It is also common to use kilohertz (kHz), megahertz (MHz) and gigahertz (GHz), where:
1 000 Hz = 1 kHz
1 000 kHz = 1 MHz

Wave speed equation

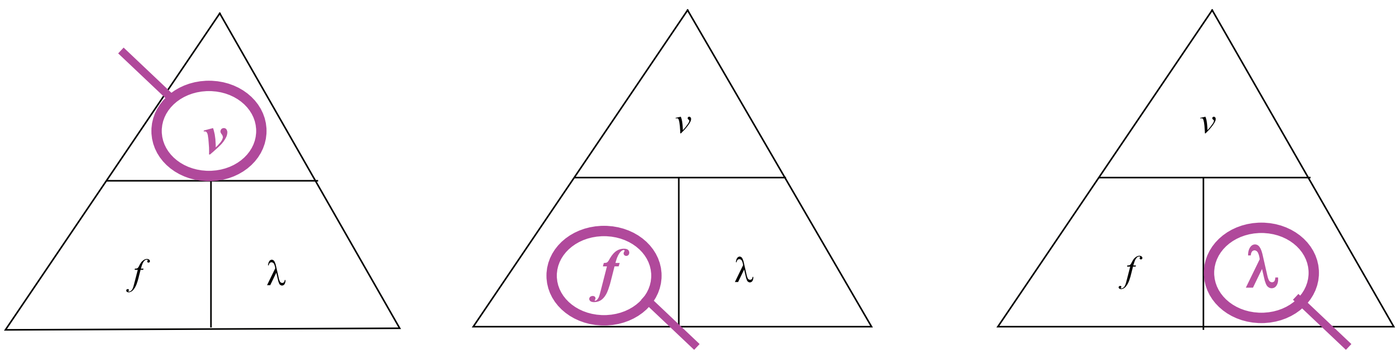
The speed of a wave is related to its frequency and wavelength, according to this equation:

wave speed = frequency × wavelength
$v = f \times \lambda$

where:

v is the wave speed in metres per second, m/s
f is the frequency in hertz, Hz
λ (lambda) is the wavelength in metres, m

If you do the higher tier exam paper then you must be able change the subject in the equation. A formula triangle may help you remember what to do.



$v = f \times \lambda$ $\quad f = v / f$ $\quad \lambda = v / f$

Foundation tier	You will always be given the equation in the form required by the question

Images from the universe

How can we learn about our universe if we cannot travel beyond our own solar system? The answer to this question is that we look carefully at the messages sent to us from the universe.

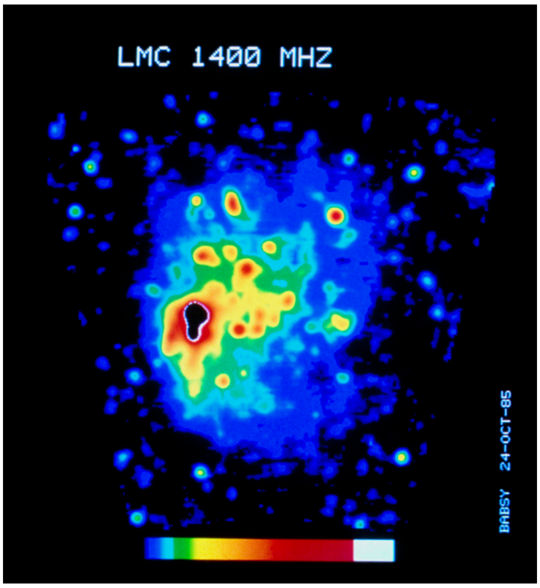
Stars emit electromagnetic radiation. That electromagnetic radiation gives us a lot of information about a star. By using telescopes sensitive to different wavelength ranges of the spectrum, astronomers can see into a wide variety of objects in the universe. We can only see the visible region of the electromagnetic spectrum with our eyes. To help us understand information from other regions of the electromagnetic spectrum, astronomers often convert the information into a false colour image.

Radio waves

If we were to look at the sky with a radio telescope, the sky would appear very different from what we see in visible light. Instead of seeing point-like stars, we would see objects such as:

- quasars - extremely distant objects. These are thought to be a region near the centre of a massive galaxy surrounding a black hole
- pulsars - rapidly rotating stars which are the dead relics of massive stars.

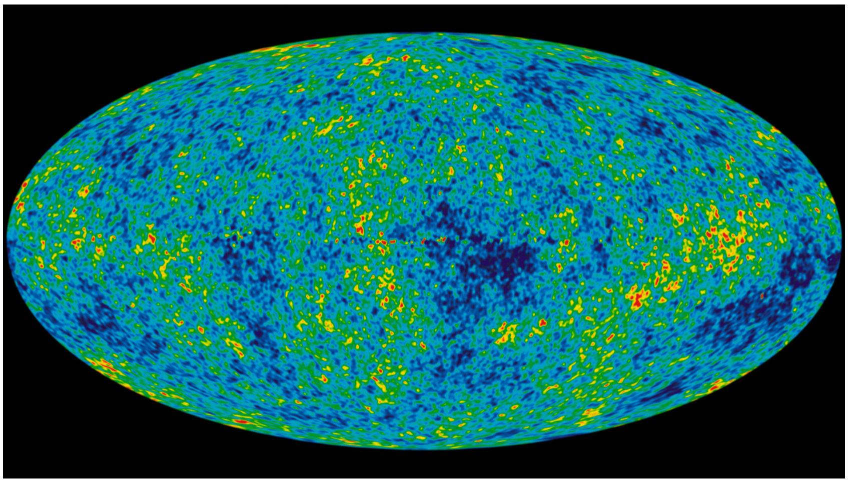
In the false colour image below, red is the region of intense radio emission, while blue is the region of least intense radio emission. Black is an area where no radio waves are emitted.



A false colour radio map of the Large Magellanic Cloud (LMC), made with a radio telescope in Australia

Microwaves

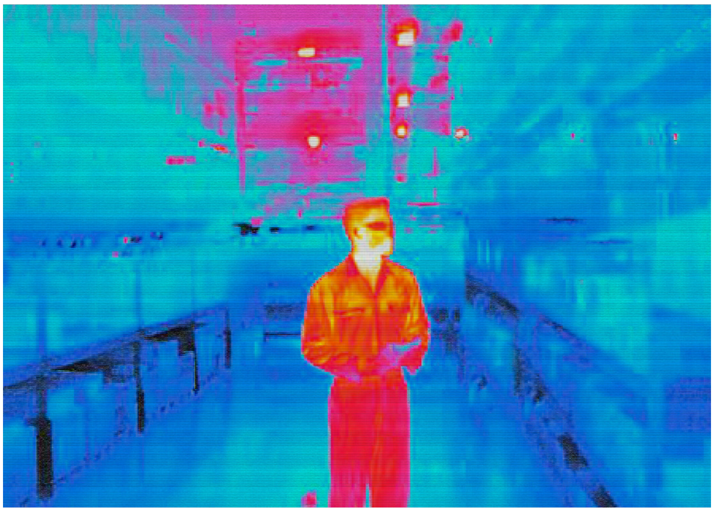
Scientists discovered that there are microwaves coming from every direction in space. This is called the cosmic microwave background radiation (CMBR). CBMR is considered to be evidence for the Big Bang theory (see the end of this section for the Big Bang theory).



Map of Cosmic Microwave Background Radiation (CMBR)
RGB Ventures / SuperStock / Alamy Stock Photo

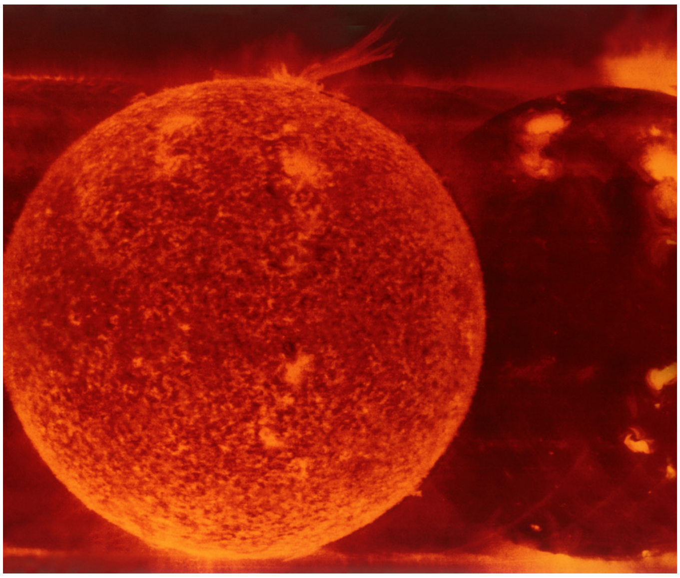
Infrared images

All objects above absolute zero emit infrared radiation.



False colour infrared image of a man in a factory
Cultura Creative (RF) / Alamy Stock Photo

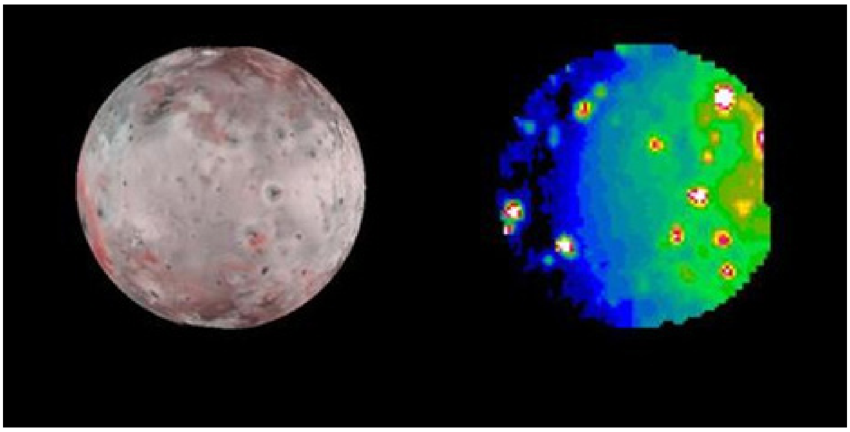
The Earth, the Sun, stars and galaxies also emit infrared radiation. More than half of the Sun's power output is in the form of infrared light.



Gas eruption at the surface of the Sun in the infrared region
mediacolor's / Alamy Stock Photo

Jupiter's moon, Io, is very far from the Sun. The temperatures on Io are cold except for the places near the volcanoes. At the volcanoes, the surface temperature can be as hot as 1 700 °C. Infrared radiation is ideal to pick up differences in temperature.

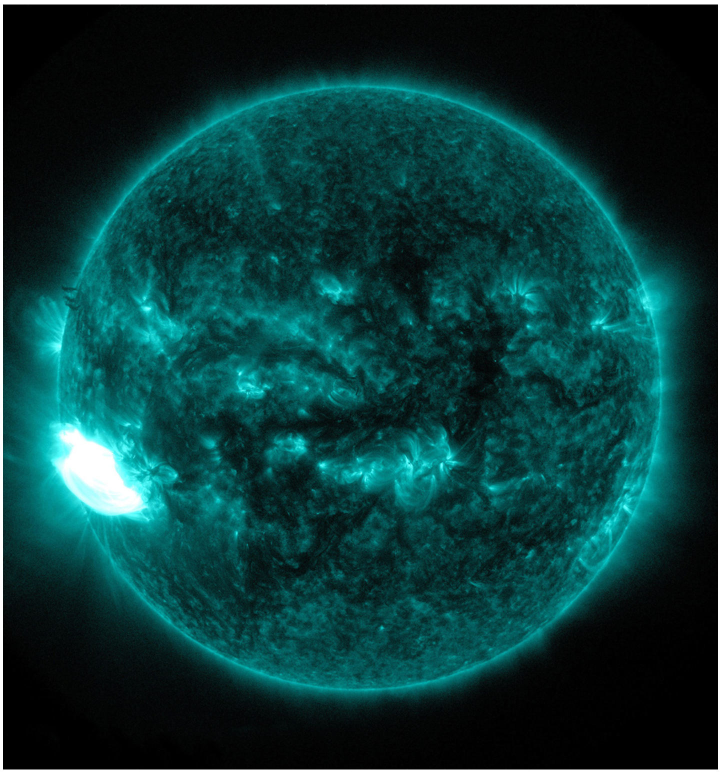
The false colour infrared image on the right below shows the hot areas associated with eruption sites. The visible image to the left helps to match geological features to these sites.



Images of Io taken in the visible and infrared regions
NASA/JPL/University of Arizona

Ultraviolet

The ultraviolet universe appears quite different from that which is seen with visible light. Most stars are relatively cool objects which emit most of their electromagnetic radiation in the visible or near-infrared part of the spectrum. These stars disappear from view when we use an ultraviolet telescope. Ultraviolet telescopes pick out the more energetic stars, such as some very young massive stars and some very old stars and galaxies, growing hotter and producing higher-energy radiation near their birth or death.



Ultraviolet Image of a solar flar
S.E.A. Photo / Alamy Stock Photo

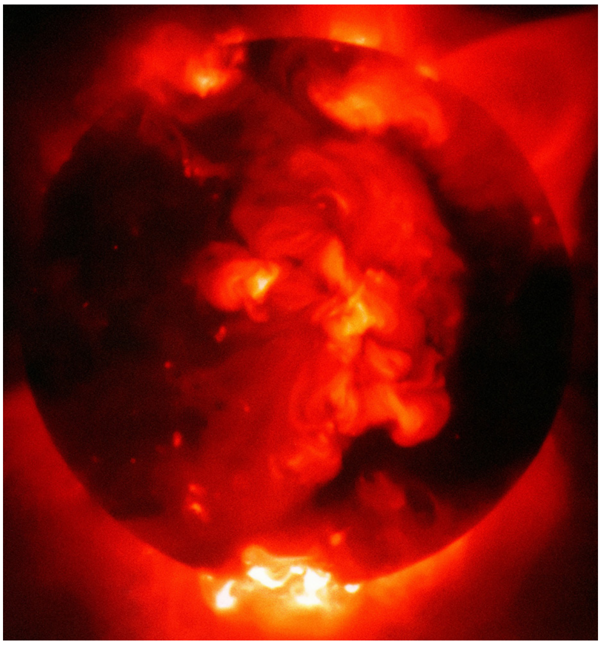
SOMETHING TO WATCH

A short video describing the information that ultraviolet radiation gives us about the galaxy, M31.

https://www.youtube.com/watch?v=5SEpa55hRO4

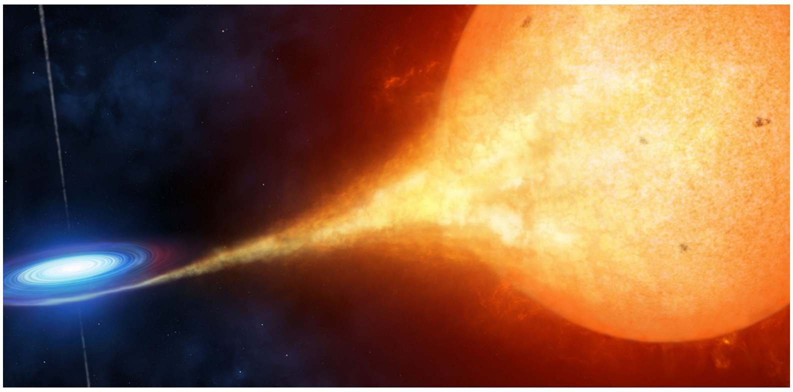
X-ray

Many things in space emit X-rays; among them are black holes, neutron stars, binary star systems, supernova remnants, stars, the Sun, and even some comets.



X-ray image of the Sun
RGB Ventures / SuperStock / Alamy Stock Photo

Many things in deep space give off X-rays, for example, a star orbiting a black hole. Material is pulled off the normal star into the black hole. As it does so it is heated up to very high temperatures and as a result gives off X-rays.



Artist's impression of a black hole ripping gas from a sun-like companion
Stocktrek Images, Inc. / Alamy Stock Photo

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Visible light

All stars emit at least some light in the visible region of the spectrum. Stars appear to be white at first glance, but closer observation shows a range of colours: blue, white, red, and even gold.

The variation in colour is a direct consequence of their surface temperature. Cool stars radiate most of their energy in the red and infrared region of the electromagnetic spectrum and thus appear red, while hot stars emit mostly at blue and ultra-violet wavelengths, making them appear blue or white.

Summary:

Region of electromagnetic spectrum	Comment
radio wave	map the structure of our galaxy
microwave	sensitive to Cosmic Microwave Background Radiation (CMBR)
infrared	measure the temperatures of planets in other solar systems peer through the dust of the Milky Way into the core of our galaxy the coldest of stars emit hardly any visible light at all; they can only be seen with infrared telescopes
visible light	most stars emit visible light the colour of a star tells us how hot it is: red stars are coolest, blue are hottest examine objects in our own solar system
ultraviolet	most of the stars and gas disappear with a UV telescope used to find the most energetic stars and identify regions of star birth
X-rays	X-rays emitted from the material around a black hole, or clouds of gas in galactic clusters that are heated to many millions of degrees.

Space based and Earth based telescopes

Optical telescopes on the ground can only be used at night and they cannot be used if the weather is poor or cloudy. Visible telescopes in space give much clearer images which are not affected by an atmosphere.

Radio telescopes can be used in bad weather because the radio waves are not blocked by clouds as they pass through the atmosphere. Radio telescopes can also be used in the daytime as well as at night.

UV and X-rays are partly blocked by the Earth's atmosphere and so need to be placed at high altitudes or placed into orbit around the Earth.

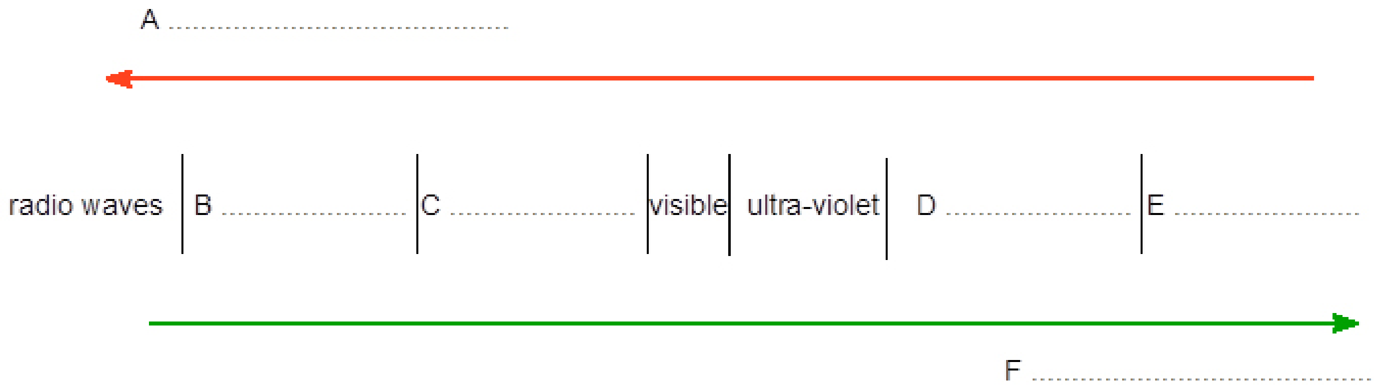
Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

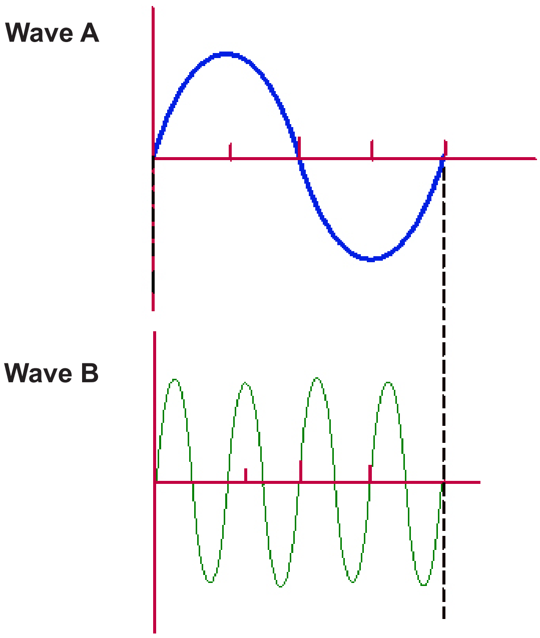
TEST YOURSELF

1. Complete the following diagram, by matching the labels from the box, to the letters in the electromagnetic spectrum.

gamma rays	**microwaves**	**infra-red**
X-rays	**increasing frequency**	**increasing wavelength**



2. The wavelength of wave A is 8 cm. Wave B is drawn to the same scale.



The wavelength of wave **B is:**

A 4 cm **B** 2 cm **C** 1 cm

TEST YOURSELF

3. Calculate the frequency of a radio wave with a wavelength of 2.0 m.

$$\text{frequency} = \frac{\text{wave speed}}{\text{wavelength}}$$

wave speed = 300 000 000 m/s (3.0×10^8 m/s)

The frequency is:

A 1.5×10^{-9} Hz (0.0000000015 Hz)

B 1.5×10^{9} Hz (1 500 000 000 Hz)

C 1.5 Hz

4. The part of the electromagnetic spectrum used to detect CMBR is:

A microwave

B radio wave

C infrared

5. The part of the electromagnetic spectrum used to detect energetic stars is:

A microwave

B infrared

C ultraviolet

6. The part of the electromagnetic spectrum used to measure the temperature of planets is:

A microwave

B infrared

C ultraviolet

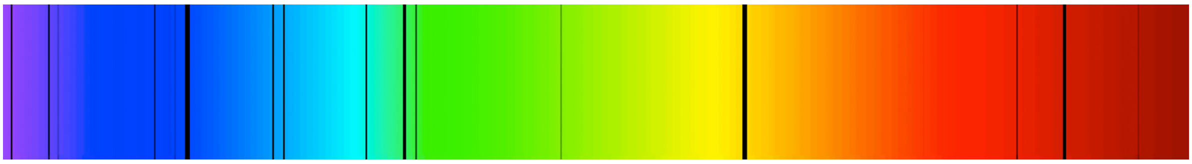
Absorption spectra

How can we know what is in the Sun or a star?

How can we know what elements are present in the Sun or a star? Once more it is by looking at the light coming from the Sun (or star). If you examine light from the Sun (or any star) you will find that there are black lines in the spectrum. These black lines are caused by elements in the **cooler outer part** of the Sun **absorbing** light coming from inside the Sun. This pattern of black lines is known as the **absorption spectrum**.

Each element has its own unique pattern of **absorption lines**; these lines form a fingerprint for each element.

The image below shows the absorption spectrum for the element helium. Helium will always cause the same pattern of lines. We can use this pattern to identify the presence of helium in the Sun (or in any other star).



Absorption spectrum
Phil Degginger / Alamy Stock Photo

By looking at the absorption spectra of the Sun we know that the Sun is composed of about 72% hydrogen and 26% helium. There are also trace amounts of other elements such as oxygen, carbon, neon, nitrogen, magnesium, iron and silicon.

You do not need to remember the composition of the Sun.

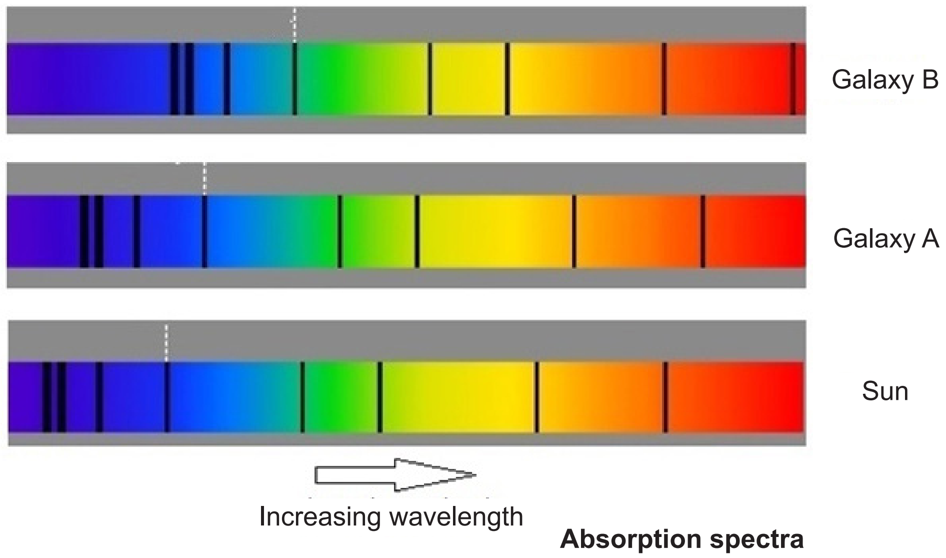
You just need to know that the absorption spectrum of the Sun tells us what elements are present.

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

How far away?

Absorption spectra can also help us determine how far away an object is.
The diagram below shows the absorption spectra caused by the same element in three different objects. Galaxy B is furthest away from us while the Sun is closest to us.



Absorption spectra
Phil Degginger / Alamy Stock Photo

In each case, the pattern of black absorption lines is the same but they are in different positions. The position of the lines shifts depending on how close the object is to us. **Astronomers have found that the further a star is from us, the more its light is shifted to the red end of the spectrum (i.e. to longer wavelengths)**. This is known as **redshift**.

Redshift tells us that distant galaxies are moving away from us, and that the further away a galaxy is, the faster it's moving away. It suggests that everything is moving away from everything else. This is evidence that the **universe is expanding**.

You will meet redshift at the end of this section when we meet the Big Bang theory.

SOMETHING TO WATCH

This is a short video in which a NASA astronomer explains the idea of redshift.

https://www.youtube.com/watch?v=Iq5BsQZ5Xeo

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Distance and the universe

It is extremely difficult for us to take in the size of the universe. The distances are almost beyond our comprehension.

The Sun is 150 million kilometres from the Earth, but that's a tiny distance compared with the distance to other stars, or other galaxies. We use a larger unit of measurement for these distances known as the light year.

A **light-year** is the distance light travels in a year.

To give you a 'feel' for the distances involved, think about the following information.
Light takes about:

- eight **minutes** to reach us from the Sun
- five **hours** to reach Pluto from the Sun
- four **years** to reach us from the next nearest star, Proxima Centauri
- 100 000 **years** to cross the Milky Way galaxy
- 13 000 **million years** to reach us from the galaxies furthest away.

To put the distance in light years, we say, 'the nearest star is four light years away; the furthest galaxies are 13 000 million light years away'.

Remember however, that measuring distances to other stars and to very distant galaxies is not easy, so the data is uncertain.

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Our Solar System

The Solar System consists of:

- **the Sun** (a star) containing 98.8% of the mass of the Solar System
- **eight planets** and their natural satellite moons containing about 0.2% of the mass of the Solar System
- five smaller **dwarf planets** (e.g. Pluto) and their natural satellite moons
- **asteroids** and **comets**

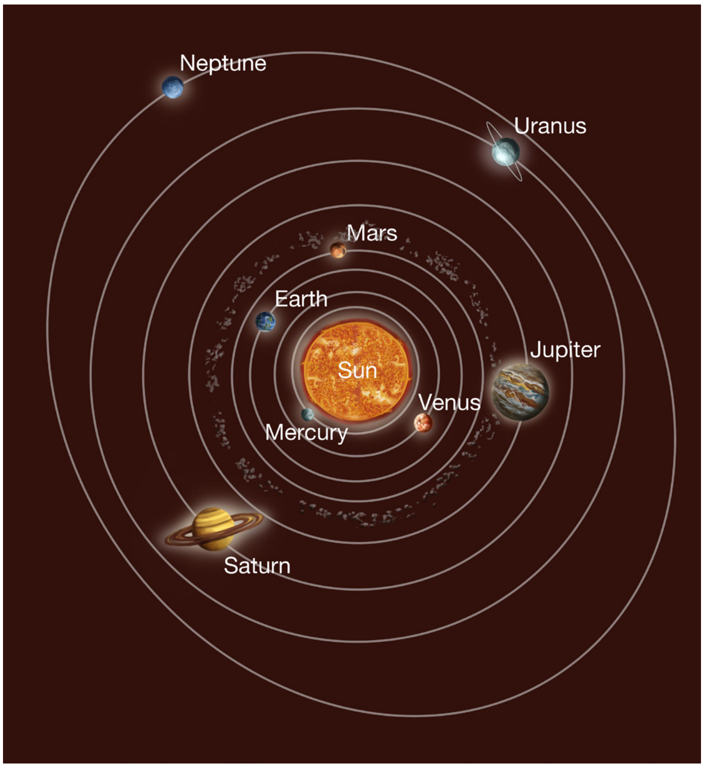


Diagram showing the orbits of the eight planets and the asteroid belt
Photo Researchers, Inc / Alamy Stock Photo

SOMETHING TO WATCH

Diagrams of the Solar System can leave us with a mistaken impression of the relative sizes of the objects and the distances involved in our Solar System. Watch this video to get a true impression of the relative sizes of objects and distances in our Solar System.

http://www.space.com/30610-scale-of-solar-system-amazing-video.html

Our planet (Unit 1.3)

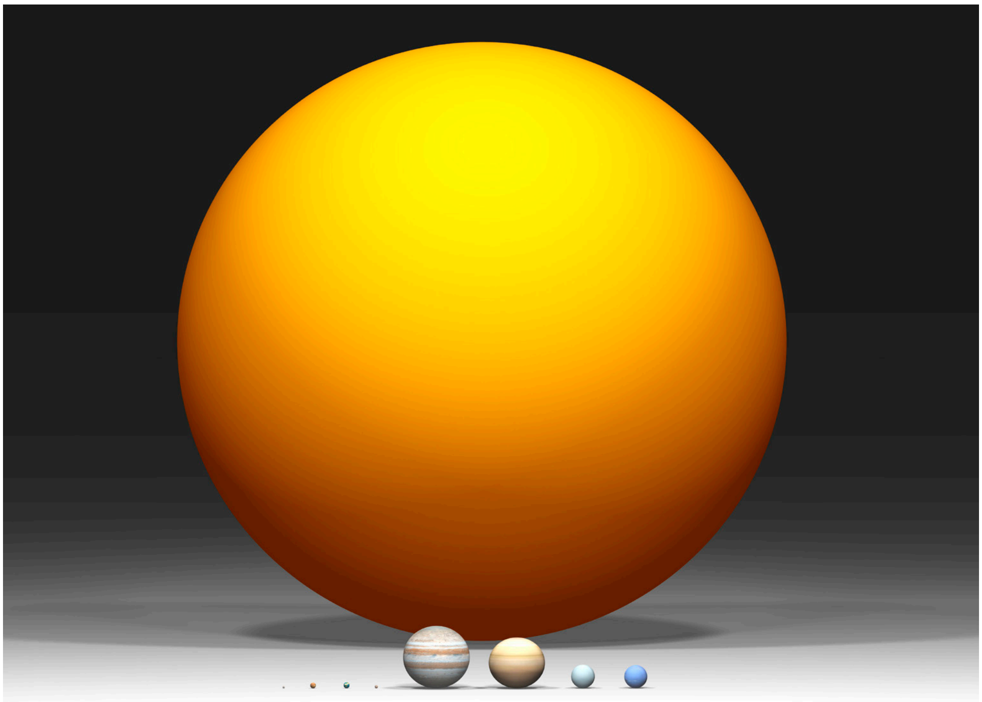
Our place in the universe (specification 1.3.1)

The Sun

The **Sun** is the largest body in the Solar System, containing **98.8%** of the total mass of the entire Solar System. It mostly consists of **hydrogen** and **helium**.

The Sun is massive compared to the Earth. Its diameter is over **100 times** that of the Earth.

Can you pick out Earth from the planets below?



The size of the Earth and other planets compared to the Sun
Science Photo Library

The Sun is the source of nearly all the energy we receive. The energy source is nuclear fusion.

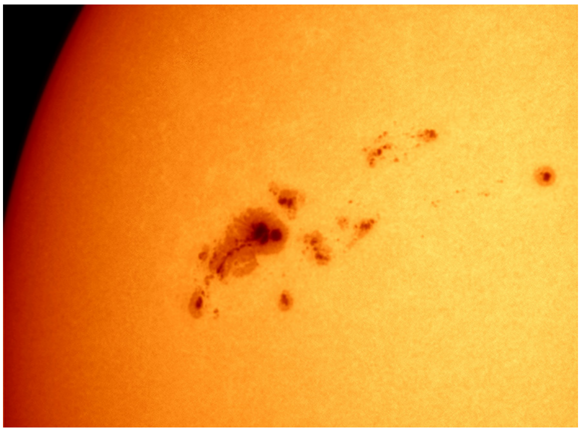
In **nuclear fusion**, hydrogen nuclei are joined together to make helium nuclei.

This releases enormous amounts of energy.

hydrogen nucleus + hydrogen nucleus → helium nucleus (+ energy)

Sunspots

Sunspots are dark spots which appear on the surface of the Sun. The spots are dark because they are cooler than the area of the Sun that surrounds them and they are often as big as the Earth. They often appear in pairs on either side of the equator, and usually last from 50 to 100 days. The number of sunspots on the surface of the Sun seems to vary over an 11 year cycle from almost zero up to over 100.



Sunspots
John Chumack / Science Photo Library

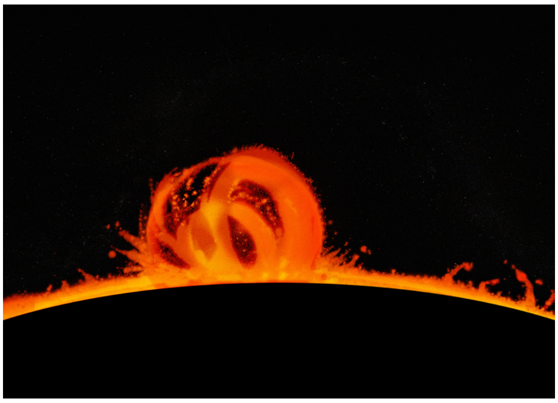
Sunspots

A **solar flare** is an intense burst of radiation coming from the release of magnetic energy associated with sunspots.

Flares are our Solar System's largest explosive events. They are seen as bright areas on the Sun and they can last from minutes to hours.

We typically see a solar flare by the light it releases at almost most every wavelength of the spectrum.

Flares are also sites where particles (electrons, protons, and heavier particles) are accelerated.



Solar flare
Photodisc / gettyimages

Solar flares can disrupt power supplies and communication systems on Earth.

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

In 1989, Quebec experienced power failure due to a solar flare. The solar flare caused high currents in the Earth's magnetosphere causing electric transformers and power stations to blow. The largest known solar flare took place on August 28, 1859. Telegraph systems failed throughout Europe and North America. Aurorae, or northern lights, were seen in many parts of the world. Similar flares would have a much more significant impact on Earth today due to our reliance on satellites and modern communication systems.

SOMETHING TO WATCH

Watch a video of a solar flare on the surface of the Sun in July 2012
https://www.youtube.com/watch?v=HFT7ATLQQx8

The Planets

The orbits of the planets in the Solar System are almost circular - with the Sun near the centre.

We can divide the planets into two groups: the rocky planets and gas giants.

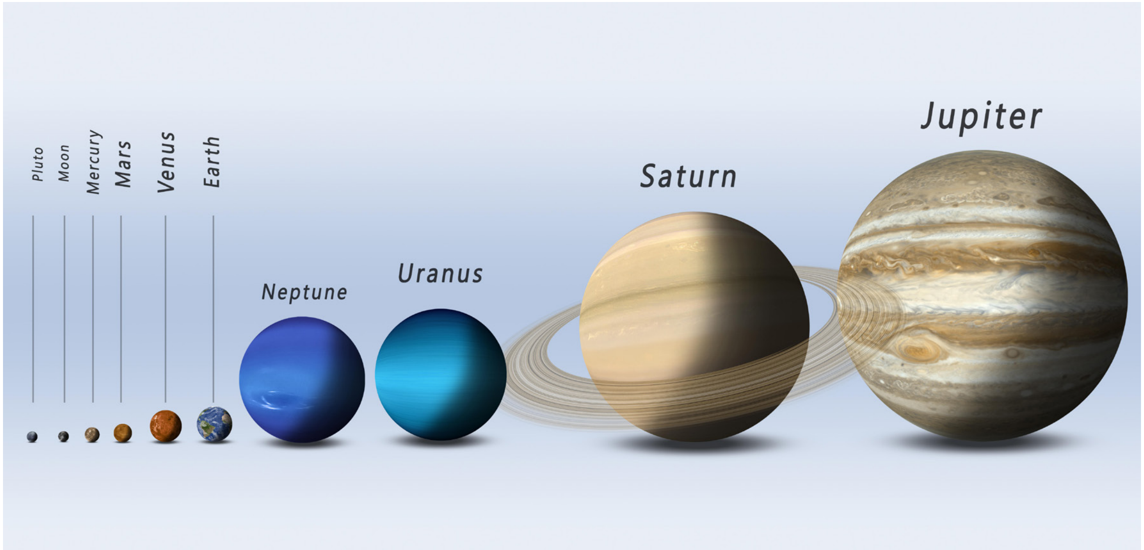
Type of planet	Planets	Composition
inner rocky planets	Mercury, Venus, Earth and Mars	similar to Earth in composition composed primarily of silicate rocks or metals
outer gas giants	Jupiter, Saturn, Uranus and Neptune	composed of gases, such as hydrogen and helium, with a relatively small rocky core

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Relative sizes of planets

The gas giants are much larger than the inner rocky planets. The relative sizes of the planets are shown by the diagram below.



Planets
Alexander Aldatov / Alamy Stock Photo

Dwarf planets

There are five officially recognised dwarf planets in our solar system The most well-known is Pluto. With the exception of one, the dwarf planets are found in the outer Solar System.

Natural satellites (moons)

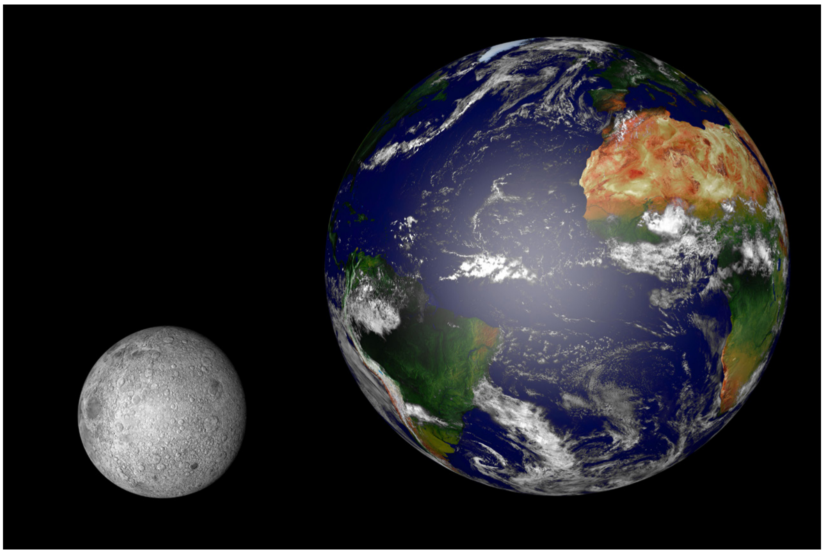
Planet	Number of moons	Example
Mercury	0	
Venus	0	
Earth	1	Moon
Mars	2	Phobos & Deimos
Jupiter	67	Io
Saturn	62	Titan
Uranus	27	Oberon
Neptune	14	

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

The Moon

The Moon is nearly a sixth of the diameter of the Earth.



Moon and Earth shown to realistic sizes
360b / Alamy Stock Photo

Phobos – a moon of Mars

Phobos is the larger and innermost of the two natural satellites of Mars. It is a small, irregularly shaped rocky object with a mean radius of 11 km. If you stood on the surface of Mars, Phobos would appear about one-third as large as Earth's moon (as seen from Earth).

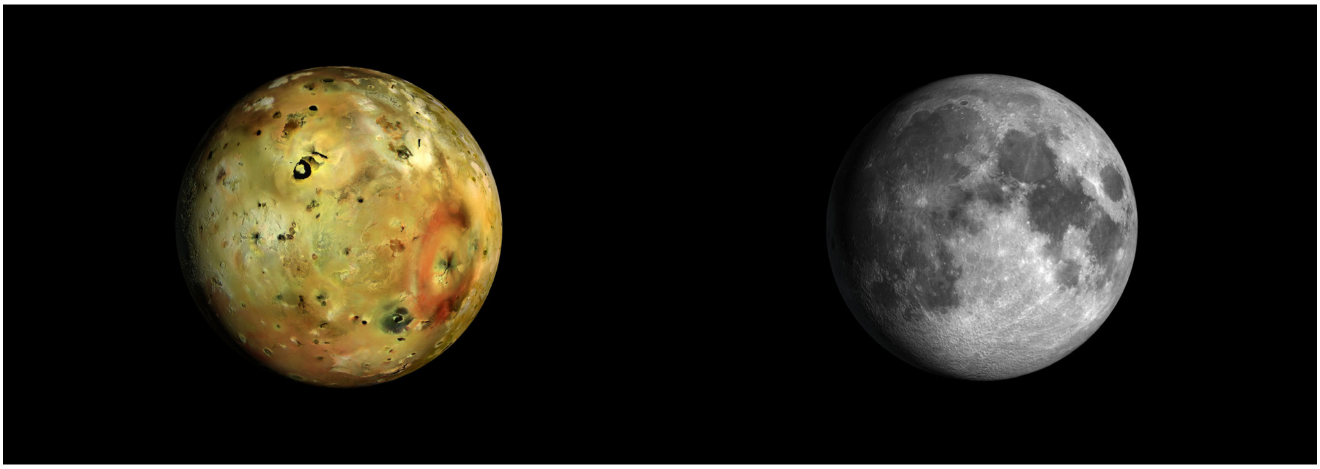
Phobos
World History Archive / Alamy Stock Photo

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Io – a moon of Jupiter

Io has been described as looking like a 'giant pizza covered with melted cheese and splotches of tomato and ripe olives'. Io is the most volcanically active body in the solar system with hundreds of volcanoes.

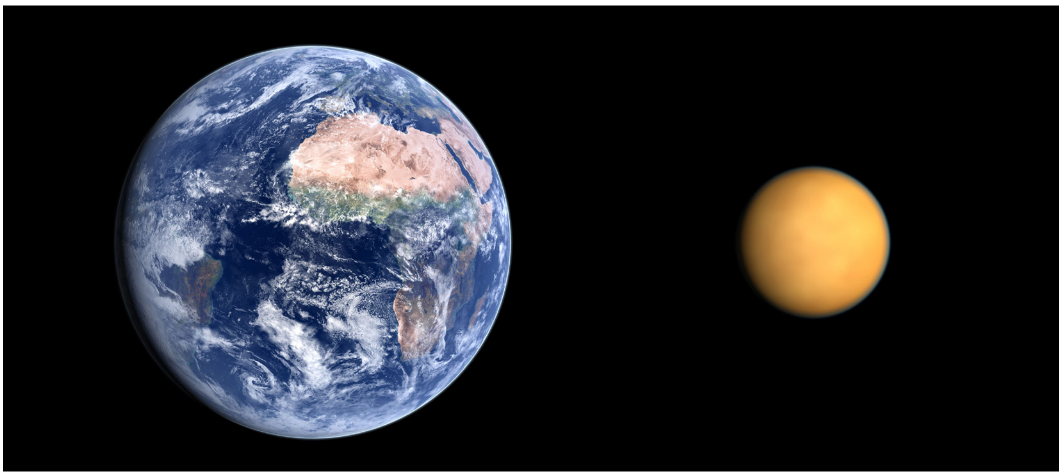


Moons
Tristan3D / Alamy Stock Photo

Titan – a moon of Saturn

Titan is Saturn's largest moon and the second largest in the solar system. It is the only moon in the solar system with clouds and a dense, planet-like atmosphere mostly of nitrogen and methane. Titan's surface is shaped by rivers and lakes of liquid ethane and methane. These form clouds and occasionally it rains from the sky.

A comparison of the relative sizes of Earth and Titan:



Earth and Titan
Tristan3D / Alamy Stock Photo

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

Oberon - a moon of Uranus

This is an old, heavily cratered moon of Uranus:

Uranus moon
World History Archive / Alamy Stock Photo

Asteroids

Asteroids are smaller than planets. They are believed to be rocks left over from the formation of the Solar System. Most are found in an 'asteroid belt' in orbit around the Sun between Mars and Jupiter.

Asteroids may crash into each other which can result in a change in their orbit. The orbits of some asteroids cross the Earth's orbit.

Comets

Comets are balls of ice and dust in orbit around the Sun. Unlike the planets which have circular orbits, the orbits of comets are elliptical. A comet's orbit takes it very close to the Sun and then far away again.

The time to complete an orbit varies - some comets take a few years, while others take millions of years to complete an orbit.

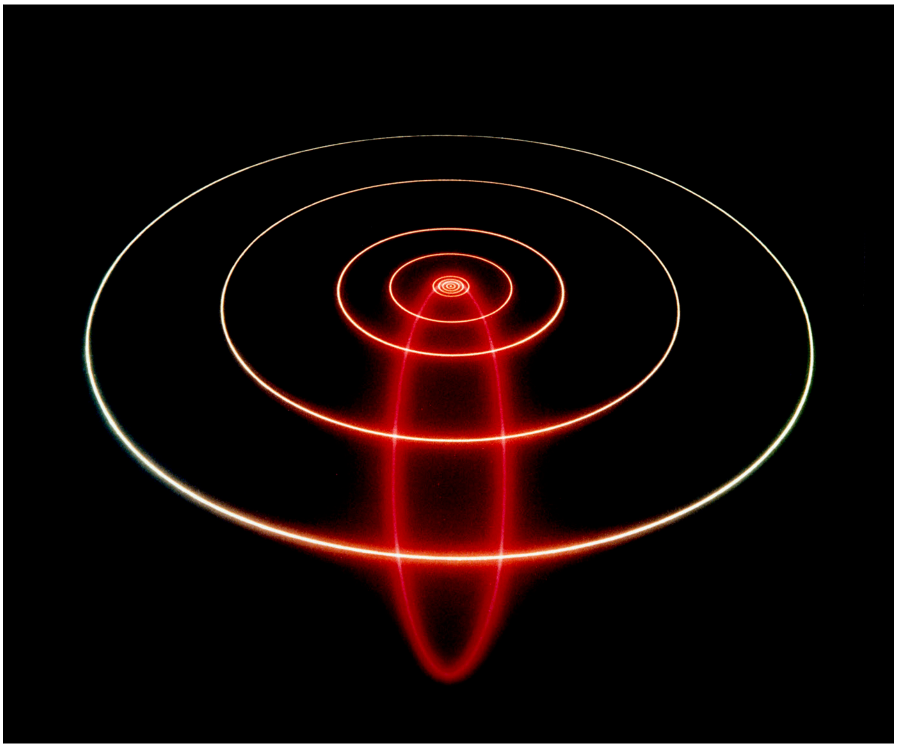


Diagram showing orbit of Halley's Comet

Julian Baum / Science Photo Library

The Oort cloud

In 1950 Jan Oort suggested that there is an enormous spherical cloud, beyond the orbit of Neptune surrounding our solar system. This is known as the Oort cloud. It is thought to extend out into space, perhaps to a distance of a light year and contains many millions of objects of different sizes.

At present, there is no direct evidence for the existence of the Oort cloud.

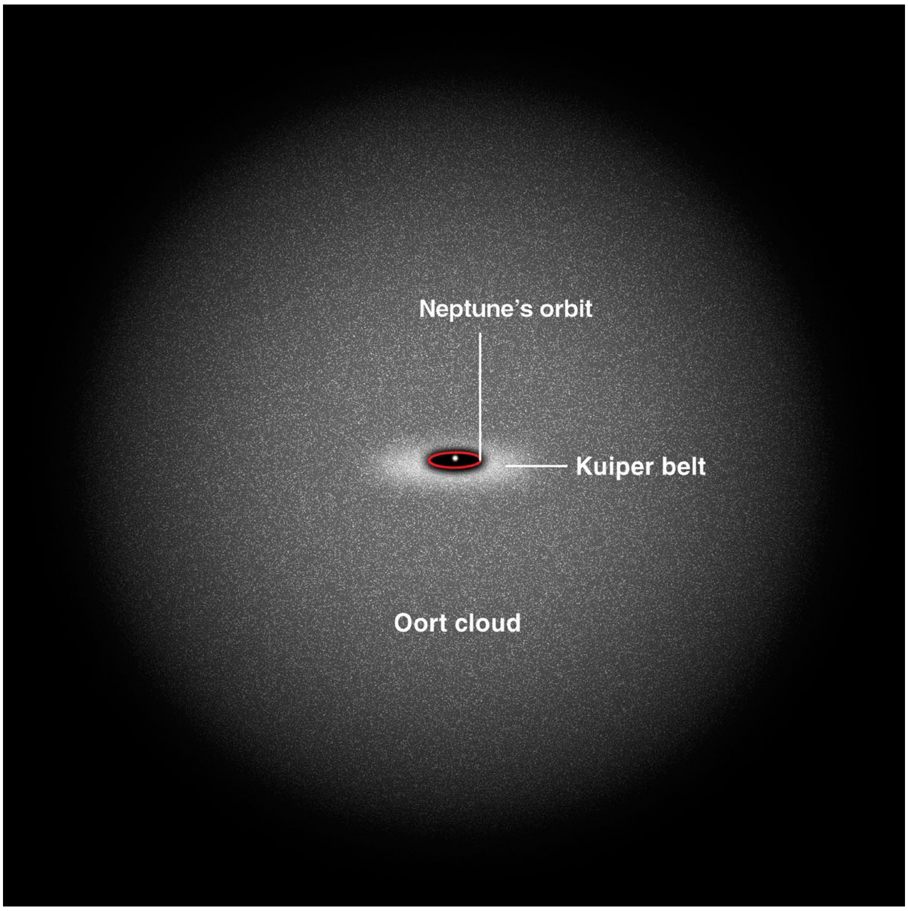


Diagram of the Oort cloud

Stocktrek Images, Inc. / Alamy Stock Photo

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

The Big Bang theory

There are a number of theories of how the Earth began. Two important theories are the:

- Steady state theory
- Big Bang theory

The main differences between the two theories are summarised below.

Big Bang theory	Steady-state theory
Universe exploded from a single point at some time about 13.7 billion years ago and is still expanding today	Universe has no beginning and no end
All the matter in the universe was concentrated into a single incredibly tiny point	The steady-state theory suggests that matter is constantly being created in empty space as the universe expands

The **Big Bang theory** is the more popular theory today. The following two pieces of evidence support this theory:

1. light from all the distant galaxies is **red-shifted** and the further away the galaxy the bigger the redshift;
2. microwave radiation comes evenly from all parts of the universe - **cosmic microwave background radiation** (CMBR).

Explanation of these observations

1. Redshift measurements mean:

    - all the galaxies are moving away from us;
    - the further away a galaxy is, the faster it is moving away.

    Both of these features are found in explosions - the fastest moving objects end up furthest away from the explosion. In other words, the evidence from redshift can be explained by the universe **expanding** from a single point source explosion.

2. **Cosmic microwave background radiation** (CMBR) comes evenly from all parts of the universe. CMBR is explained as radiation left over from an early stage in the development of the universe. The CMBR is a snapshot of the oldest light in our universe, imprinted on the sky when the universe was just 380 000 years old.

Our planet (Unit 1.3)

Our place in the universe (specification 1.3.1)

TEST YOURSELF

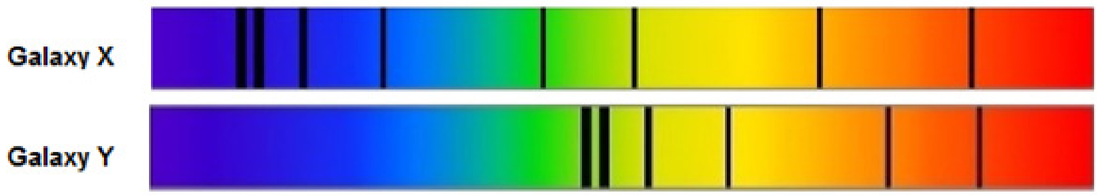
1. The name of the region from which it is believed that comets originate is the:

A Oort cloud
B Asteroid belt
C Inner part of the Solar System

2. Select the correct statement about the orbits of planets and comets.

A Planets have an elliptical orbit but comets have a spherical orbit
B Both planets and comets have elliptical orbits
C Both planets and comets both have circular orbits
D Planets have a spherical orbit but comets have an elliptical orbit

3. State which of the following galaxies is furthest from the Sun.



A Galaxy X is further away than galaxy Y
B Galaxy Y is further away than galaxy X
C Galaxy X and galaxy Y are about the same distance away

TEST YOURSELF

4. Match the following moons to the description on the right by drawing a line from the moon to the description. One has been done for you.

Name of moon	**Feature**
Io	only moon in the solar system with clouds and a thick atmosphere
Phobos	most volcanically active body in the solar system with hundreds of volcanoes
The Moon	the larger and innermost of the two natural satellites of Mars
Titan	it is about 1/6th the size of the planet it orbits

PRACTICE QUESTIONS

1. (a) The table gives some information about the planets in our solar system. Use the information in the table to answer the questions that follow.

Planet	Mean distance from sun (AU)	Diameter (1 000s km)	Time to spin once on axis (Earth days)	Time to orbit Sun (Earth years)	Average temperature (°C)	Known moons
Mercury	0.4	5	59	0.2	427	0
Venus	0.7	12	243	0.6	480	0
Earth	1.0	13	1	1	14	1
Mars	1.5	7	1	2	-63	2
Jupiter	5.2	143	0.4	12	-130	63
Saturn	9.5	120	0.4	29	-130	61
Uranus	19.2	51	0.7	84	-200	27
Neptune	30.0	50	0.7	165	-200	13

(i) Place a tick (✓) in the box next to the correct statements. [3]

Gas giant planets have more moons than rocky planets. ☐

The time taken by Earth to spin once on its axis is the same as the time taken to orbit the Sun once. ☐

The further a planet from the Sun the bigger it is. ☐

A day on Mars is the same duration as on Earth. ☐

There is no greenhouse effect on Mercury. ☐

Mars has the closest orbit to Earth. ☐

PRACTICE QUESTIONS

(ii) The dwarf planet Ceres is the largest object in the asteroid belt, which lies between the orbits of Mars and Jupiter.
Estimate the temperature on Ceres. [1]

temperature = …………°C

(b) Complete the sentences below about the universe. [5]

(i) The universe began as the result of an ………………….. known as the Big Bang.
(ii) The universe continues to ……………………………… away from the Big Bang.
(iii) The universe is estimated to be 13.5 thousand ………………………… years old.

Science in the Modern World (Unit 1)

Our planet (Unit 1.3)

World of life (specification 1.3.2)

Our planet (Unit 1.3)

World of life (specification 1.3.2)

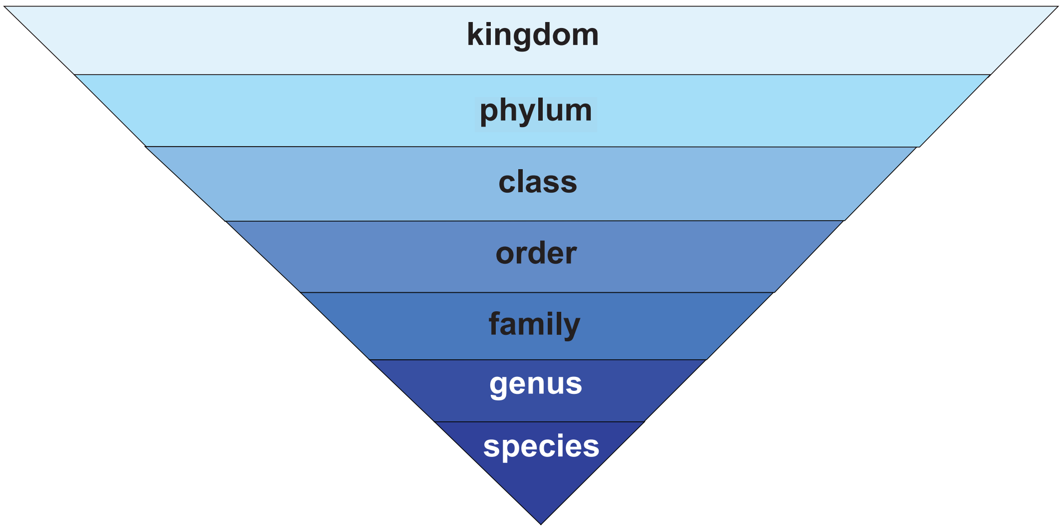
Classification of organism

There are millions of different organisms on our planet. It is helpful to classify organisms into groups.

Classifying organisms helps us understand the relationship between organisms and it also helps us accurately identify and understand an unknown organism.

The binomial system

The modern system of classifying organisms was developed by Carolus Linnaeus and is called the binomial system.
In this system we separate organisms into smaller and smaller groups. The groups are:



Remember the order:

King Philip Came Over For Good Soup

Kingdoms are the broadest group and contain the most organisms. As you go down the list, each group gets smaller and contains fewer organisms.

Our planet (Unit 1.3)

World of life (specification 1.3.2)

Kingdoms

This is the broadest group. It is based upon what an organism looks like. These are called morphological features. The five kingdoms and some of their key features are described in the table below:

Kingdom	Feature
animal (all multicellular animals)	• multicellular • feeds on other organisms
plants (all green plants)	• cellulose cell wall • use light energy to produce food
fungi (moulds, mushrooms, yeast)	• cell wall • produce spores
bacteria	• no nucleus
single celled animals (e.g. amoeba, chlorella and plasmodium)	• one cell • some plant and animal characteristics

Classifying species

To classify a species we first put the organism into one of the kingdoms listed above
We then use a logical system to place the organism into a 'narrower' group.
For example when we classify plants we can divide plants into:

- **non-flowering plants** such as ferns and mosses
- **flowering plants** which do produce flowers

In the case of animals, we can either put them into the vertebrate phylum **or** one of the inveterate phyla. (Phyla are just the plural of phylum)

Vertebrates are animals with a backbone; **invertebrates** are animals that do not have a backbone.

Examples of vertebrates

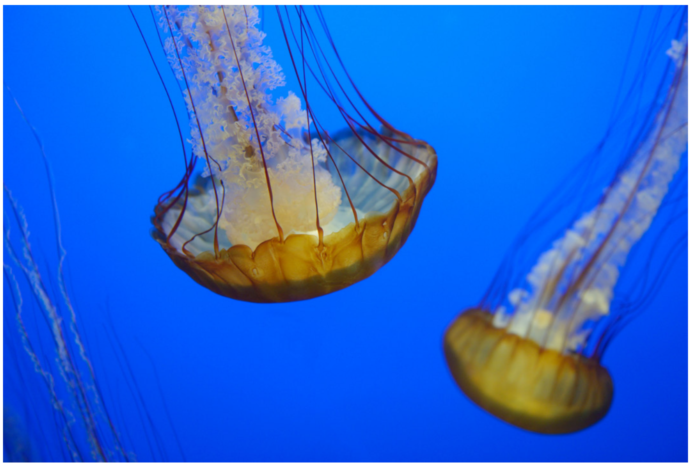
Squirrel
Rick & Nora Bowers /
Alamy Stock Photo

Owl
David Fleetham /
Alamy Stock Photo

Frog
WILDLIFE GmbH /
Alamy Stock Photo

Examples of invertebrates

Crab spider
Sabena Jane Blackbird /
Alamy Stock Photo



Jellyfish
Martin Shields /
Alamy Stock Photo

Our planet (Unit 1.3)

World of life (specification 1.3.2)

Classifying organisms and scientific name

The table below shows how three well known animals are classified using this system. Notice that we use Latin words to classify the animals.

The **scientific name** of the organism is made of two parts, the **genus** and the **species**.

Group	House cat	Lion	Dog
kingdom	Animalia	Animalia	Animalia
phylum	Chordata	Chordata	Chordata
class	Mammalia	Mammalia	Mammalia
order	Carnivora	Carnivora	Carnivora
family	Felidae	Felidae	Canidae
genus	***Felis***	***Panthera***	***Canis***
species	***domesticus***	***leo***	***familiarus***
Name	***Felis domesticus***	***Panthera leo***	***Canis familiarus***

Some advantages of using a scientific name

The scientific name tells us about the classification of an organism and shows its relationship to other animals. It gives us more information than a common name and helps avoid confusion between organisms. It also gives us a naming system that scientists can use worldwide, again avoiding confusion between the names of organisms in different languages or even in different parts of the same country.

For example, the name 'robin' is used in the UK to describe quite a different bird to the one called robin in the USA.

UK robin (*Erithacus rubecula*)
David Cole / Alamy Stock Photo

American robin (*Turdus migratorius*)
Arterra Picture Library / Alamy Stock Photo

Other classification system

Cladistics is another way to classify organisms. It can use data from DNA or RNA sequences, rather than just physical characteristics. It emphasises the evolutionary relationships between different species.

Our planet (Unit 1.3)

World of life (specification 1.3.2)

TEST YOURSELF

Answer the questions below based upon the table.

Group	Lion	Tiger	Grey wolf
kingdom	Animalia	Animalia	Animalia
phylum	Chordata	Chordata	Chordata
class	………………..	Mammalia	Mammalia
order	Carnivora	Carnivora	Carnivora
family	Felidae	Felidae	**W**
genus	*Panthera*	*Panthera*	**X**
species	*leo*	*tigris*	**Y**

1. The class that the lion belongs to is:
A Chordata
B Carnivora
C Mammalia

2. The scientific name for a lion is:
A Felidae Panthera
B *Panthera leo*
C leo

3. The scientific name of the grey wolf is *Canis lupus*. It belongs to the same order as the lion but to the Canidae family.

A W is Canidae, X is *Panthera*, Y is *lupus*
B W is Felidae, X is *Canis*, Y is *lupus*
C W is Canidae, X is *Canis*, Y is *lupus*

ADAPTATION TO THE ENVIRONMENT

In order to survive in an environment, organisms need to:

- be adapted to the environment
- survive alongside other living things.

To do this, organisms:

- may have special structural or behavioural adaptations
- obtain essential resources (food, water (and minerals for plants)) from the environment
- may need to compete with other organisms for essential resources
- compete for mates with other organisms of the same kind.

Adaptations to extreme conditions

Since there is constant competition for resources among organisms, those that are best suited to an environment are most likely to survive. Over many generations organisms have become suited to their environment. In other words, they have adapted to the environment.
Some habitats such as deserts or the Arctic are very difficult places to live in and organisms need to be well adapted to these environments if they are to survive. Animals that live in the Arctic also tend to be relatively large. This helps to decrease the surface area to volume ratio, minimising heat loss.

Penguins

Wings
Wings are not of any use to fly but act as flipper that power the penguin through water.

Blubber
Penguins have lots of blubber (fat) under their skin to insulate them.

Feet
The webbed feet are used as rudders in water.

Body shape
Streamlined body reduces drag when swimming.

Feathers
Tightly packed and waterproof outer plumage keeps penguins dry and warm.

More on the feet
Arteries in the penguins' legs are able to adjust the blood flow to the feet based on temperature.

Blood flow is restricted when it is colder, reducing heat loss through the feet.

Penguin
Andy Myatt / Alamy Stock Photo

Cacti

Spines

Cacti have spines instead of leaves to reduce surface area to minimise water loss.

They also protect the cacti from animals who may want to eat them.

Water storage

Stems of the cacti store water.

Root system

Cacti have wide-spread root systems to collect water from a large area.

Cacti
All Canada Photos / Alamy Stock Photo

SOMETHING TO WATCH

Watch a video describing how the Namaqua Chameleon is adapted to the Nambi desert.

https://youtu.be/AkzUuResd5Q

Behavioural adaptations

In addition to structural adaptations to fit an organism to an environment, organisms may adopt behavioural strategies such as hibernation or migration to deal with extreme environmental conditions.

Examples

Bird migration

- Birds (e.g. swans and geese) migrate from areas where food resources or nesting locations are low or decreasing, to areas of high or increasing resources.
- Birds that nest in the Northern Hemisphere tend to migrate northward in the spring to take advantage of increasing insect populations, budding plants and an abundance of nesting locations.
- As winter approaches and the availability of insects and other food drops, the birds move south again.

Hibernation

Some animals (e.g. hedgehogs, dormice and bats) hibernate as a means of dealing with extreme environmental conditions.

- The metabolism of a hibernating animal slows and its temperature plunges. Breathing slows and the heart rate falls.
- In order to survive hibernation, mammals feed heavily in summer and autumn, storing fat to see them through the winter.
- Hibernation is not without danger however. Animals may die during hibernation from lack of fat, severe weather or premature awakening.

Hibernating dormouse

FLPA / Alamy Stock Photo

SOMETHING TO WATCH

Watch a video describing the migration of some common British birds.

http://www.bbc.co.uk/guides/zqrggk7

Our planet (Unit 1.3)

World of life (specification 1.3.2)

BIODIVERSITY

Biodiversity is a term that describes the variety of living things on earth.
In short, it is described as a measure of variation of life. Biodiversity encompasses microorganisms, plants, animals and ecosystems such as coral reefs, forests, rainforests, deserts etc.
Biodiversity also refers to the number, or abundance of different species living within a particular region.

Biodiversity describes the variety of living organisms in a particular habitat or in the world as a whole

There are many reasons for maintaining biodiversity. Biodiversity helps to:

- maintain the balance of the ecosystem. Losing an organism may:
    - affect other organisms in the food web;
    - have unexpected consequences such as erosion caused by deforestation.
- provide biological resources. Some organisms may provide a:
    - useful source of drugs;
    - food for human populations and animals
    - products for industry or homes
- social benefits. A wide biodiversity also helps human well-being.

Facts to think about

- 80% of the human food supply comes from 20 kinds of plants. But humans use 40 000 species for food, clothing and shelter. Biodiversity provides a variety of foods for the planet. It may be important for us to be able to draw on this genetic diversity to provide new food crops in the future.
- Biodiversity also plays an important role in drug discovery and medicinal resources. Medicines from nature account for usage by 80% of the world's population.
- Biological sources provide many industrial materials. These include fibre, oil dyes, rubber, water, timber, paper and food.

Measuring biodiversity

It is often not possible to count all the organisms in a population. For example, the area to be monitored may be very large and not practical to measure the total population. In such a case it is necessary to **estimate** the total population size by **sampling**.

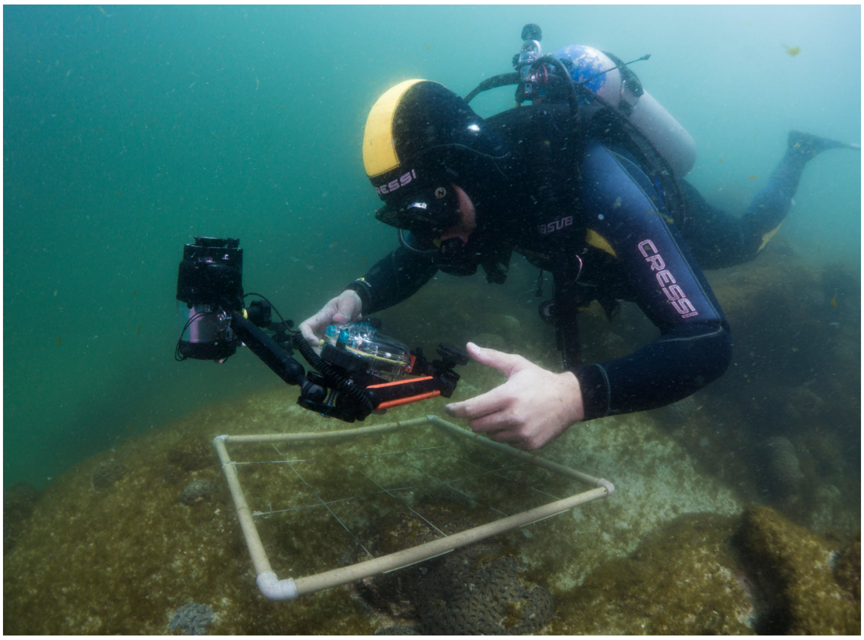
One method of sampling involves using a quadrat.

Using a quadrat

A quadrat is a square frame used to sample an area. They are placed **randomly** in the area to be studied.

Quadrats are useful for studying plants or slow moving animals such as snails.

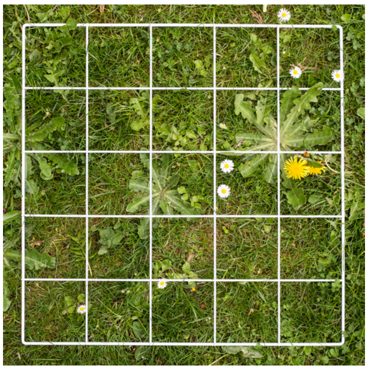
They may be used in other contexts as well, e.g. monitoring a coral reef.



Scuba diver using photo quadrat
Leo Francini / Alamy Stock Photo

The individuals of each species in the quadrat are then identified and counted. This information may then be used to estimate population sizes.

Worked example



Quadrat
Science Photo Library

Estimate the number of dandelions in a field.

Twenty 1 m^2 quadrats are randomly placed to sample a field 500 m^2 in area.

73 dandelions were counted in total.

Total sample area = 20 × 1 = 20 m^2

The estimated population size of dandelions in the field would be

$$\frac{\text{total area (m}^2\text{)}}{\text{total sample area (m}^2\text{)}} \times \text{total number of dandelions in sample}$$

$$\text{estimated population of dandelions} = \frac{500}{20} \times 73 = 1\,823$$

Remember:

When using a quadrat:

- it should be placed randomly so that a representative sample is taken
- the validity and reproducibility of the results increases as the results from more quadrats are analysed

Our planet (Unit 1.3)

World of life (specification 1.3.2)

NATURAL SELECTION AND EVOLUTION

Natural selection

What is **Natural Selection**?

'The organisms best adapted to their environment tend to survive and transmit their genetic characteristics in increasing numbers to succeeding generations, while those less well adapted tend to be eliminated'.

In more detail:

- Individuals in a species show a wide range of variation due to differences in their genes.
- The individuals with characteristics most suited to the environment are the most likely to survive and reproduce.
- The genes that allowed the individuals to be successful are passed to the offspring in the next generation.
- Individuals that are poorly adapted to their environment are less likely to survive and reproduce. This means that their genes are less likely to be passed to the next generation.
- Over a long period of time the species will change.

"**Survival of the fittest**" is a way of describing the mechanism of natural selection. It means that organisms which have a slight advantage over others are more likely to survive **and breed**.

It is better remembered as "**survival of the fittest to breed**".

Evolution and natural selection

The basic idea behind the theory of evolution is that all the different species evolved from simple life forms. It is believed that simple life forms first developed more than three billion years ago and have gradually developed over a long period of time.

Charles Darwin first developed the idea of natural selection as the **driving force** behind evolution.

Pale peppered moth
Frank Hecker / Alamy Stock Photo

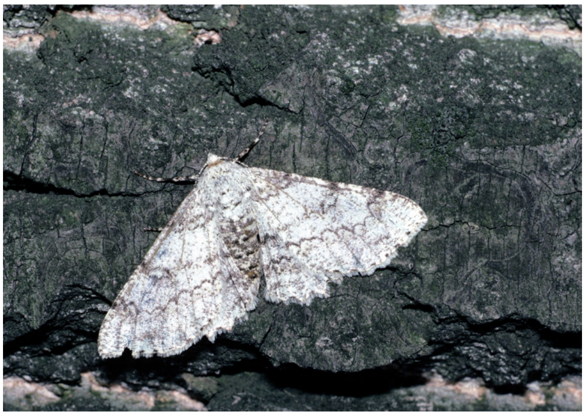
The peppered moth

Before the industrial revolution in Britain, most peppered moths were a pale variety. This meant that they were camouflaged against the pale birch trees that they rest on.

Moths with a black colouring were easily spotted and eaten by birds. This gave the pale variety an advantage, and they were more likely to survive to reproduce.

Black peppered moth against a light background
blickwinkel / Alamy Stock Photo

When airborne pollution in industrial areas blackened the birch tree's bark with soot, the situation reversed. The black moths were now camouflaged, while the pale variety became more vulnerable to predators. This gave the black variety an advantage, and they were more likely to survive and reproduce.
Over time, the black peppered moths became far more numerous in urban areas than the pale variety.

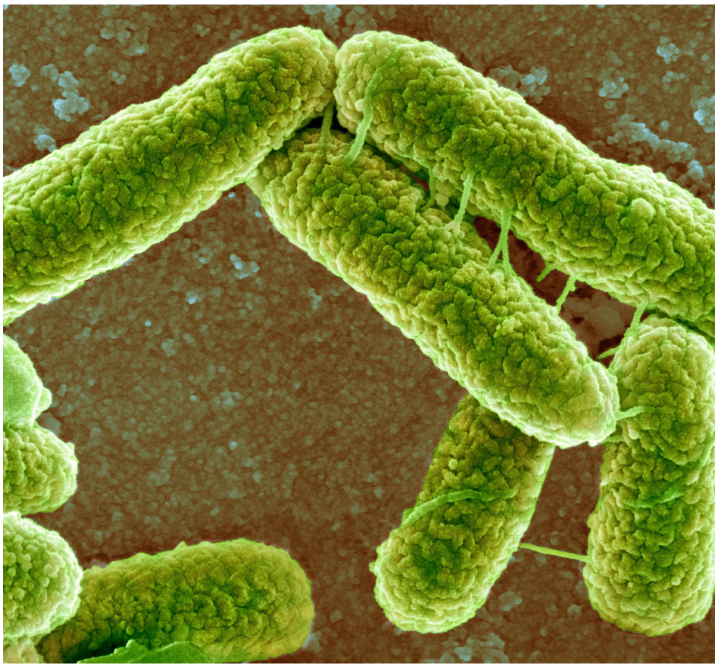


Pale moth against dark background
INTERFOTO / Alamy Stock Photo

Antibiotic resistance

E. coli is an example of a bacterium which, like other bacteria, reproduces very rapidly. This gives the potential for the bacteria to rapidly adapt to their environment.
During replication a mutation may occur (its DNA can be changed). Very often a mutation causes the death of the cell, but occasionally, it is beneficial for the bacteria. A mutation may, for example, allow the bacteria to become resistant to an antibiotic. When that antibiotic is present, the resistant bacteria have an advantage over the bacteria that are not resistant.

Antibiotic-resistant strains of bacteria are an increasing problem in hospitals.



Coloured electron micrograph of *E. coli* bacteria
Science Photo Library / Alamy Stock Photo

Warfarin resistant rats

Another example of Natural Selection is of rats becoming resistant to the rat poison Warfarin.

- Warfarin kills most rats but a few are resistant to Warfarin
- Warfarin is used by people to kill rats
- The resistant rats survive to breed and pass on their genes to the next generation
- The number of **resistant** rats increases with each generation.

TEST YOURSELF

1. Polar bears are able to survive in the extreme conditions of the Arctic more easily than smaller animals because:

   A Polar bears lose heat more quickly than small animals
   B They have a large surface area to volume ratio compared to smaller animals
   C They have a small surface area to volume ratio compared to smaller animals

2. Lloyd is studying the population of snails in a field. The total area of the field was 200m^2. He uses a quadrat to study the field. He uses a 1m^2 quadrat to randomly take five samples of the field. The results from his sampling are shown below.

Quadrat number	Number of snails
1	4
2	6
3	1
4	0
5	2

   (a) Use his results to estimate the population of snails in the field
   A 520
   B 13
   C 65

   (b) He could improve his estimate of the snail population by:
   A choosing where to place the quadrats
   B taking more care when counting the snails
   C taking 15 samples from the field instead of 5

3. Which phrase best describes the term 'survival of the fittest"
   A Survival of the fittest means that individuals which have a slight advantage over others are more likely to survive
   B Survival of the fittest means that individuals who have a slight advantage over others are more likely to survive and breed.
   C Survival of the fittest means that individuals who have a slight advantage over others are more likely to live longer.

PRACTICE QUESTIONS

1. Tour guides in Arizona USA are learning about the adaptation of snakes.

(a) State what is meant by the term adaptation and explain why this occurs in nature. [2]

....

....

....

....

(b) The guides learn to tell the difference between the non-venomous king snake and the venomous coral snake.

King snake
Robert Hamilton / Alamy Stock Photo

Coral snake
Rick & Nora Bowers / Alamy Stock Photo

Explain the advantages to king snakes of looking like a coral snake. [2]

....

....

....

Science in the Modern World (Unit 1)

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

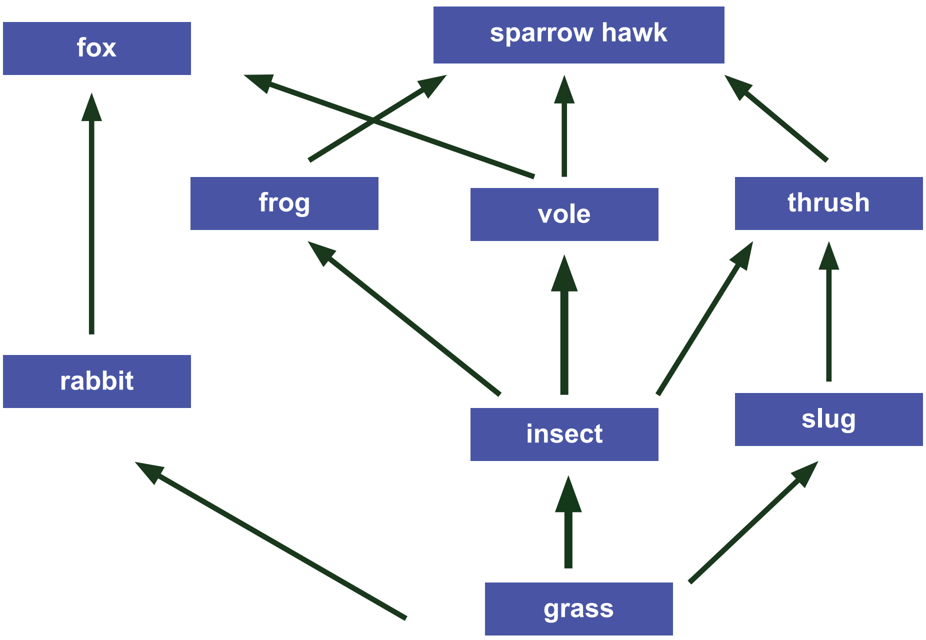
Chains, webs and pyramids

Food chains and food webs

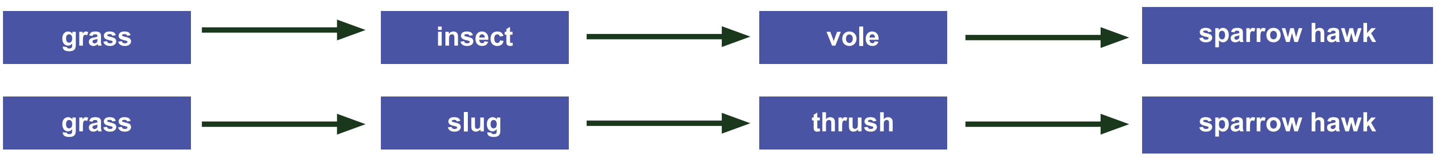
A **food chain** shows a sequence of feeding relationships and the transfer of useful energy between organisms. It traces just one path through a food web.

A **food web** consists of a network of **interconnected** food chains.

Example of a food web



Two examples of food chains that form part of this food web are:



Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

Plants that **start** food chains by making food from carbon dioxide and water, using energy from the Sun, are known as **producers**.

In the food chains, grass is the producer.

A **primary consumer** is an organism that eats the producer. Since producers are plants, primary consumers are herbivores.

In each of the chains shown in the food web, rabbits, insects and slugs are primary consumers.

A **secondary consumer** is an organism that eats a primary consumer.

For example, a vole is a secondary consumer in the food chain

A **tertiary consumer** is an organism that obtains its energy by eating the secondary consumer.

The sparrow hawk eats the secondary consumer, the vole. The sparrow hawk is therefore a tertiary consumer.

It is possible that some animals in a food web can be in different levels. For example, the fox is a secondary consumer or tertiary consumer depending upon the food chain we examine:

grass → insect → frog → fox

grass → rabbit → fox

Trophic levels

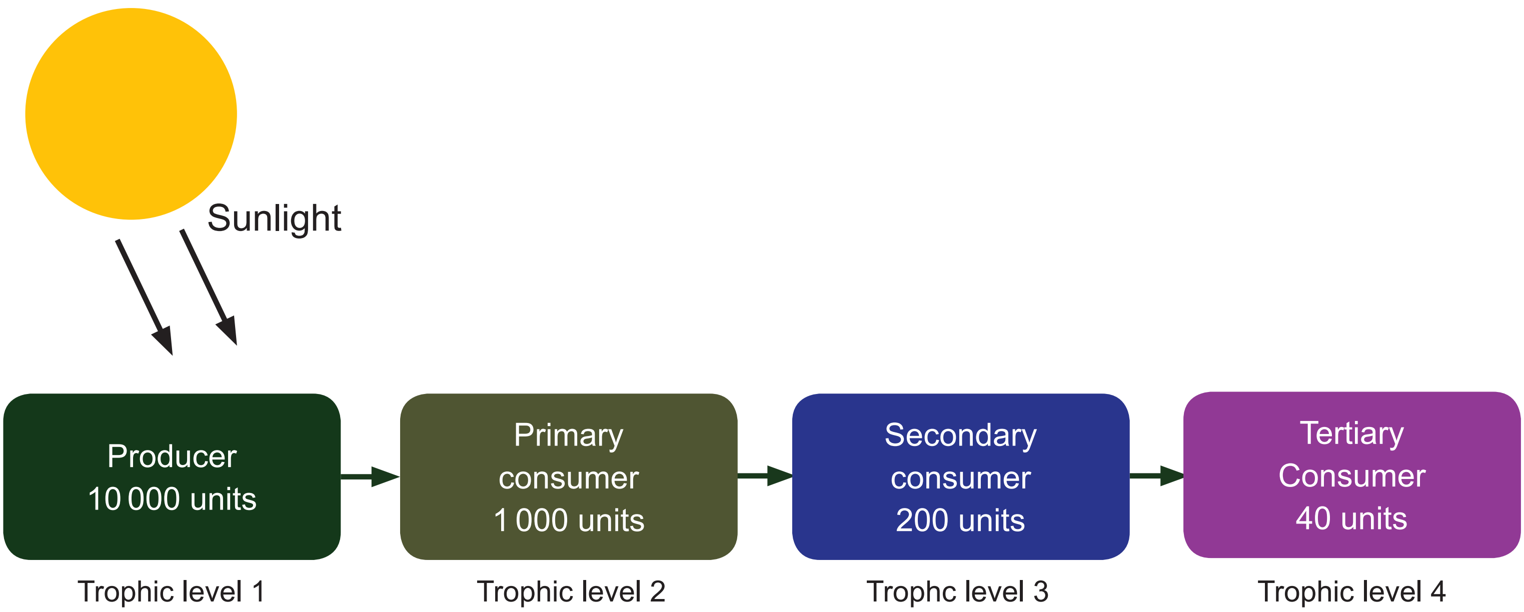
The **trophic level** of an organism is the position it occupies in a food chain, food web or pyramid.

Food chains start at trophic **level 1** with producers such as plants. Primary consumers are at trophic level 2, and so on.

Energy flow through the food chain

The sun's radiation is the primary energy source for living things.

The diagram below shows the energy flow through a particular food chain



Green plants only use a small percentage of the solar energy that reaches them. Much of the energy is reflected. Plants capture this energy by using photosynthesis.

In the food chain above, only 1 000 of the 10 000 units of energy are transferred from the producer (trophic level 1) to the primary consumer (trophic level 2).

The **efficiency of energy transfer** from the producer to the primary consumer can be calculated using:

$$\text{efficiency of energy transfer} = \frac{\text{energy transferred}}{\text{total energy in}} \times 100\,\%$$

In this case:

$$\text{efficiency of energy transfer} = \frac{1\,000}{10\,000} \times 100\,\% = 10\,\%$$

The efficiency is low because it is difficult to digest plant food.

Between the second and third trophic level, the efficiency of energy transfer is:

$$\frac{200}{100} \times 100\,\% = 20\,\%$$

The **overall** percentage energy transfer from the **producer** to the **tertiary consumer** is:

$$\frac{40}{10\,000} \times 100 = 0.4\,\%$$

This low percentage explains why it is unusual to have more trophic levels in a food chain; too much energy is already lost for animals at higher tropic levels to find food.

Energy is lost in the food chain:

- as waste from organisms by excretion and egestion (undigested solid waste)
- as heat when organisms respire
- since animals use some energy to move about.

Pyramids of biomass and pyramids of number

Biomass is the dry mass of organisms in each step of a food chain.

A **pyramid of biomass** is a scaled diagram showing the mass of living matter at each stage in a food chain.

Biomass always **decreases** from one trophic level to the next just like the amount of energy.

Do **not** confuse a pyramid of biomass with a pyramid of numbers. A pyramid of numbers shows the number of organisms at each trophic level in a food chain.

Example

Consider the food chain

oak tree → **aphid** → **ladybird**

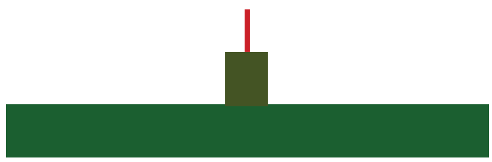
Answer the questions below based upon the table.

Organism	Number of organisms	Biomass
oak tree	1	500 000
aphids	10 000	1 000
ladybirds	200	50

We can represent the information as a pyramid of numbers and as a pyramid of biomass.

Pyramid of numbers

Pyramid of biomass



Making food production more efficient

The amount of material and energy decreases as we pass from one trophic level to the next. Food production is therefore more efficient if the food chain is short.

The efficiency of food production can also be improved by reducing the amount of energy lost by animals in the food chain.

Mammals and birds maintain a constant body temperature using energy released by respiration. As a result, their energy losses are high. If their surroundings are kept warm then this reduces energy losses.

Energy is also used up if animals move about. Restricting movement of the animal will mean less energy is lost. However, this raises serious animal welfare issues: Is it cruel to restrict animal movement? Does it reduce the quality of life of the animal concerned? A balance needs to be maintained to ensure animal welfare is maintained as well as efficient food production

Battery-raised chickens. Restricted movement reduces energy loss.
studiodr / gettyimages

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

TEST YOURSELF

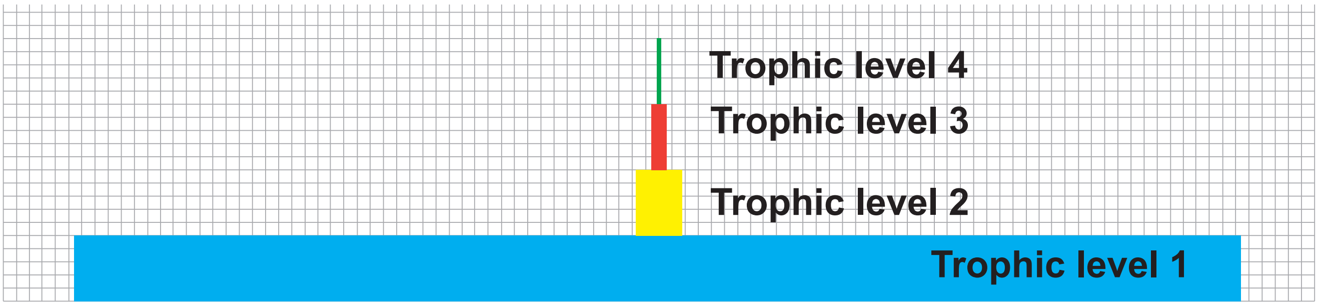
1. Select the correct word to complete the sentences below.

   Producers are (**small / animals / plants**). Producers are found at trophic (**level 1 / level 2**).

   Producers are eaten by (**secondary / primary)** consumers.

   Secondary consumers are found trophic level (**1 / 2 / 3**).

2. Select the set of data that was used to construct the pyramid of biomass shown below.



Organism	Biomass		
	DATA **A**	DATA **B**	DATA **C**
producer	809	1.5	1
primary consumer	37	11	809
secondary consumer	11	37	11
tertiary consumer	1.5	809	1.5

A Data **A**
B Data **B**
C Data **C**

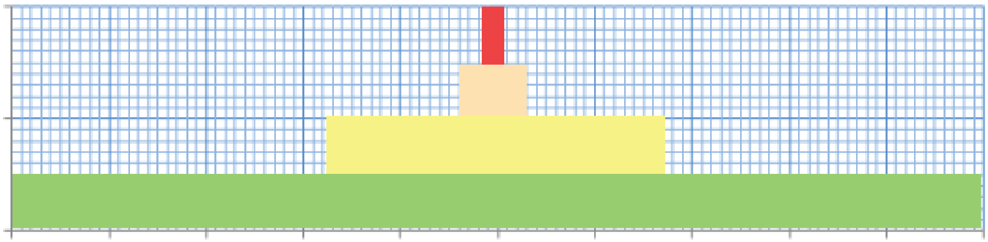
Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

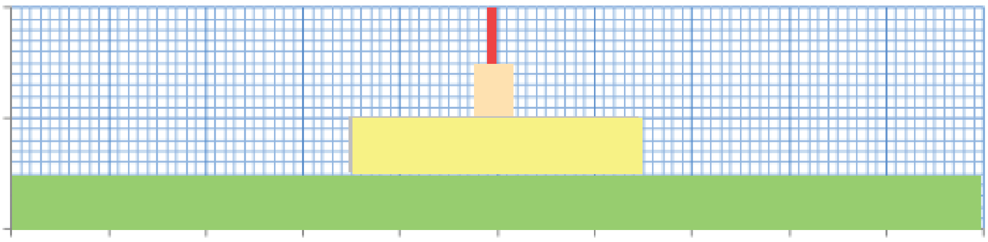
3. Select the pyramid of number (**A, B, C, D**) that correctly displays the information in the table for the following food chain, clover → snails → frogs → thrush

Organism	Number
clover	100
snails	30
frog	4
thrush	1

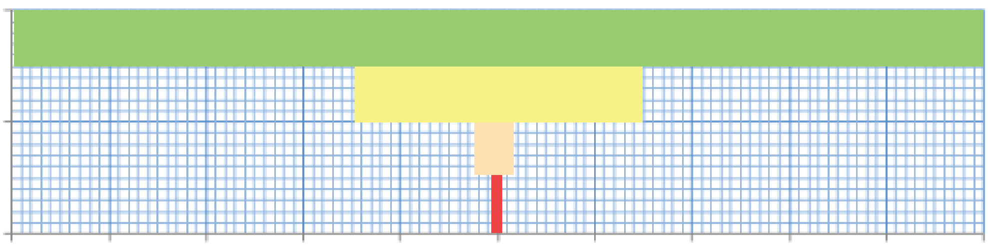
A



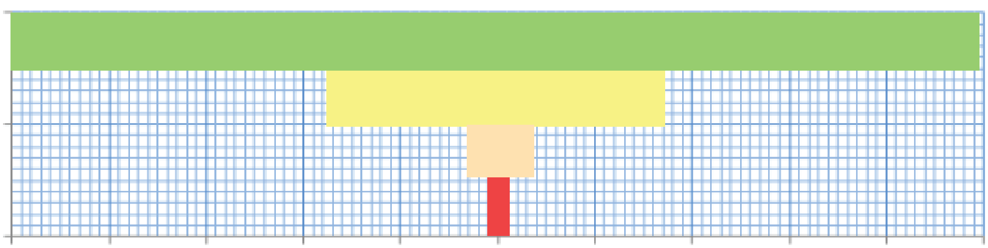
B



C



D



Interdependency of organisms

All living things within an ecosystem depend upon each other. Thus if there is a change in the size of one population, the population of other organisms within the ecosystem will be affected in some way.

Plant – animal interdependence

In ecosystems, animals and plants depend on each other in many different ways.

- Plants carry out photosynthesis and help regulate the levels of oxygen and carbon dioxide in the atmosphere.
- Plants also provide food for animals.
- Some animals depend on plants to provide them with a home or provide shelter from the environment.

Animals can also provide important services for plants.

- Animals, such as bees, can act as pollinators for flowering plants
  Without pollinators, pollination would not take place, seeds would not be produced and flowering plants would fail to reproduce.
- Animals can also assist plants in seed dispersal. They can do this by eating fruit and then dropping the seed or by excreting it later. Some seeds can attach to the coats of animals and so be transported to a new place where they may grow.

Bees pollinating pink flower
Tapsiful / gettyimages

Lesser Burdock - can become attached to coats of animals
John Glover / Alamy Stock Photo

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

Factors that affect populations

Populations of organisms in a habitat are affected by factors such as:

- competition
- predation
- disease

These factors are known as **environmental selection** pressures and they determine which individuals will live or die; i.e. which will do best at surviving and reproducing?

Competition

Where there are many different organisms living together in a habitat, they will often need to compete for the same resources.

Animals will compete for:	Plants will compete for:
• food • water • territory	• light • water • nutrients • space

The more organisms there are in a habitat, the more competition there is. The competition may be:

- between members of the same species (intraspecific competition)
- between different species (interspecific competition)

Competition between species

Interspecific competition occurs when members of di ferent species compete for a shared resource.

Competition between members of the same species

Intraspecific competition occurs when members of the **same** species compete for limited resources. Members of the same species have very similar resource requirements. Resources not only include food, water and space **but may also include mates**.

If every member of the species has sufficient resources then individuals will not need to compete and the population will grow rapidly.

Intraspecific competition can be more important than interspecific competition. For example, competition between grey squirrels is likely to have a bigger impact on the population of grey squirrels than competition with red squirrels.

Red deer stag fighting for mates: An example of intraspecific competitio
Naturfoto-Online / Alamy Stock Photo

The relationship between predator and prey populations

Predation is where a predator feeds on its prey. The interdependency of organisms within an ecosystem is clearly shown by the relationship between **predator** and **prey populations**.

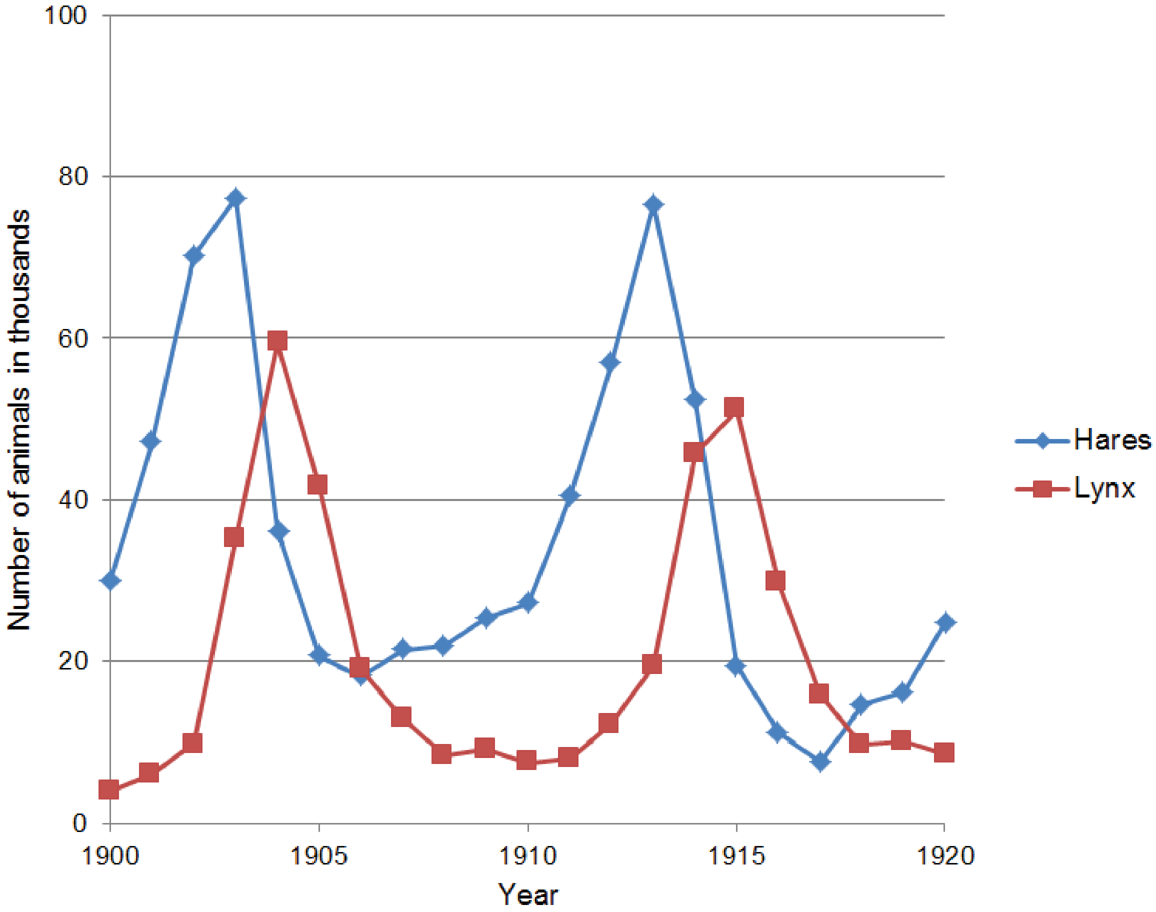
There is a continuous struggle between predators and their prey for survival. Predators need to be adapted for efficient hunting if they are to catch enough food to survive. Prey species must be well adapted to escape their predators if enough are to survive for the species to continue.

The relationship between the two populations can be shown on a **predator-prey graph**.
A typical of the predator-prey relationship is that of the lynx and the snowshoe hare.

Snowshoe hare
Naturfoto-Online/Alamy Stock Photo

Lynx
imageBROKER/Alamy Stock Photo

The graph below shows the relationship between the lynx (predator) and snowshoe hare (prey) between 1900 and 1920.



Notice that on the graph predator numbers peak slightly after the numbers of prey numbers peak. This is typical of **predator-prey cycles**.

Explanation

- When the hare (prey) population increased, the lynx (predator) population responded to the increased food source by increasing.
- As the lynx numbers increased, the higher numbers eventually reduced the hare numbers to the point where the lynx population could no longer be sustained, and so the lynx population fell.
- As the predator numbers decreased more hares were able to survive and the numbers of hares started to increase. The whole cycle started once again.

Our planet (Unit 1.3)

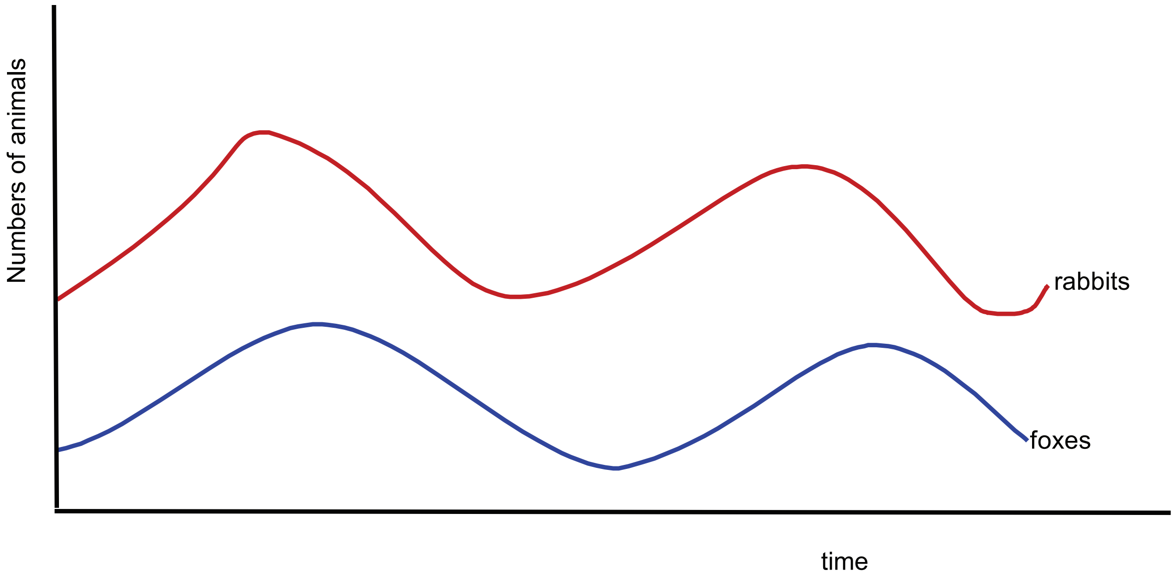
Transfer and recycling of nutrients (specification 1.3.3)

TEST YOURSELF

1. A population will grow rapidly if:

- **A** predator numbers increase
- **B** individual members of the species are forced to complete for resources
- **C** individual members of the species have sufficient resource

2. Explain the changes of the fox and rabbit populations below by selecting the correct words from the brackets.



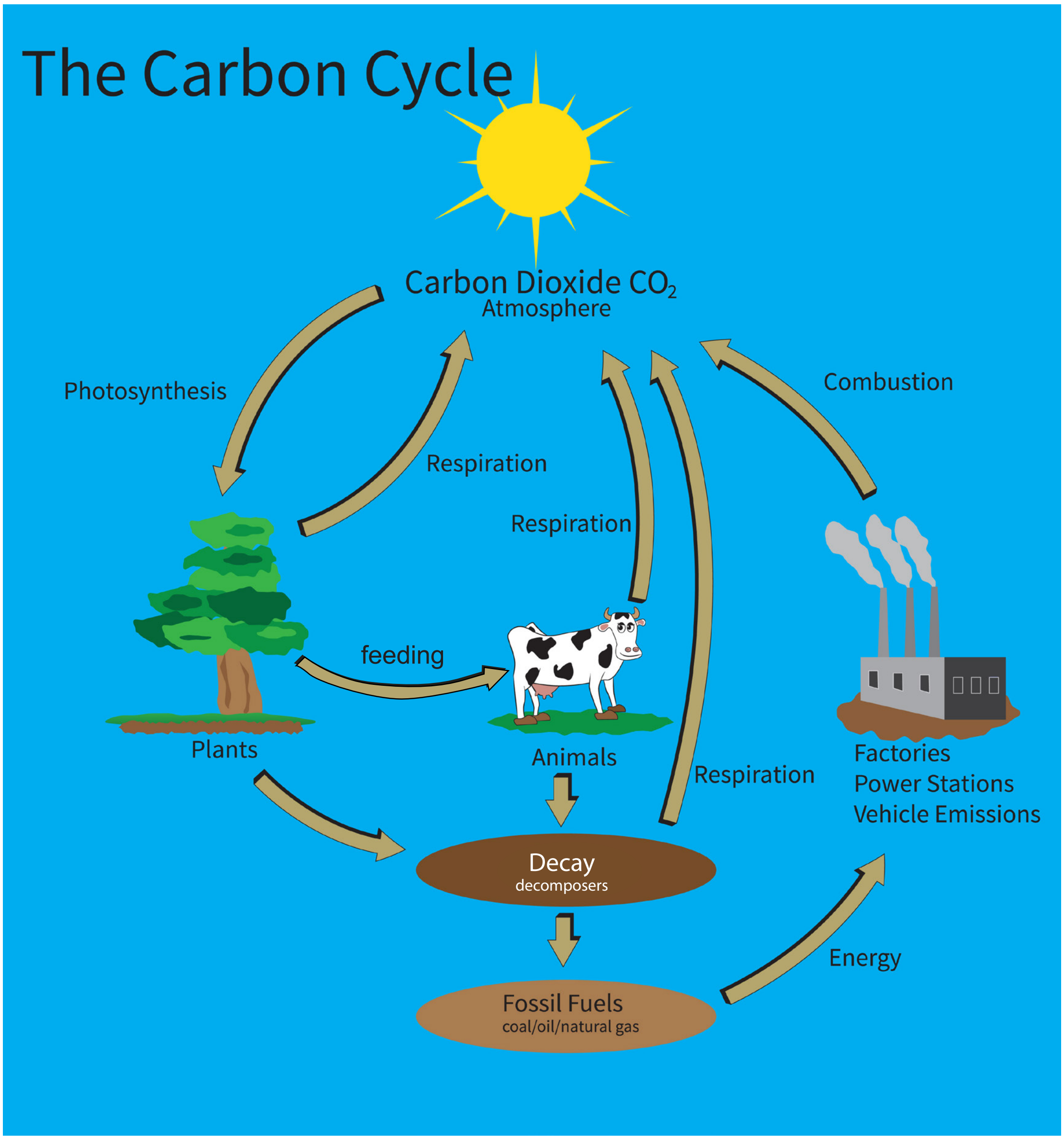
- When the rabbit population increases, the fox population which is the (prey predator), increases because there is an (decreased / increased) food source.
- As the (prey / predator) numbers increase, the higher numbers eventually reduce the rabbit numbers to the point where the fox population can no longer be sustained, and so the fox population starts to fall.
- As the (prey / predator) numbers decrease, more rabbits are able to survive and the number of rabbits starts to increase. The whole cycle begins again.

THE CARBON CYCLE

Carbon is absolutely essential to life on Earth. All organisms contain carbon since they all contain proteins, fats and carbohydrates.

The movement of carbon, in its many forms, between the atmosphere, oceans, biosphere, and geosphere is described by the **carbon cycle**.

The diagram below shows some of the important processes responsible for the movement of carbon.



Carbon cycle
Photiconix / Alamy Stock Photo

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

Processes involved in the carbon cycle

Removing carbon dioxide from the atmosphere

Green plants **remove carbon dioxide** from the atmosphere by **photosynthesis**.

The carbon becomes part of complex molecules such as proteins, fats and carbohydrates in the plants.

Returning carbon dioxide to the atmosphere

Organisms **return carbon dioxide** to the atmosphere by **respiration.**

Remember: Plants and microorganisms respire as well as animals.

Passing carbon from one organism to the next

Carbon is passed from one organism to the next through food chains.

1. When an animal feeds on plants, it takes carbon from the plants into its body. The carbon becomes part of the fats, carbohydrates and proteins in the animal.
2. Microorganisms, some animals and fungi feed on waste materials, and the remains of dead animals and plants.

Worm
Arterra Picture Library / Alamy Stock Photo

The carbon then becomes part of these microorganisms and these feeders.
e.g. An earthworm feeds on rotting plant leaves and other organic material.

Fungus
William Arthur / Alamy Stock Photo

Bacteria and fungi are also examples of decomposers. They play an important part in the recycling of organic material by digesting dead plant material. They release enzymes onto the dead material, breaking down the large molecules into soluble chemicals which are then used in respiration and for raw materials.

3. In certain conditions, when decay is prevented, animal and plant remains may eventually form fossil fuels (i.e. coal, oil and gas). Fossil fuels act as stores of carbon and energy.

Human activity and the carbon cycle

The **two** main human impacts on the carbon cycle are:

- Deforestation
- Burning of fossil fuels

1. **Deforestation**

Deforestation on the Brazilian border
luoman / gettyimages

Large amounts of carbon are stored in living plants. Therefore deforestation influences the carbon cycle in two ways:

- the removal of vegetation - Plants are no longer capturing carbon from the atmosphere through photosynthesis
- dense forests are replaced by crops or pasture land - Less carbon is stored in small plants than large trees

2. **Burning of fossil fuels**

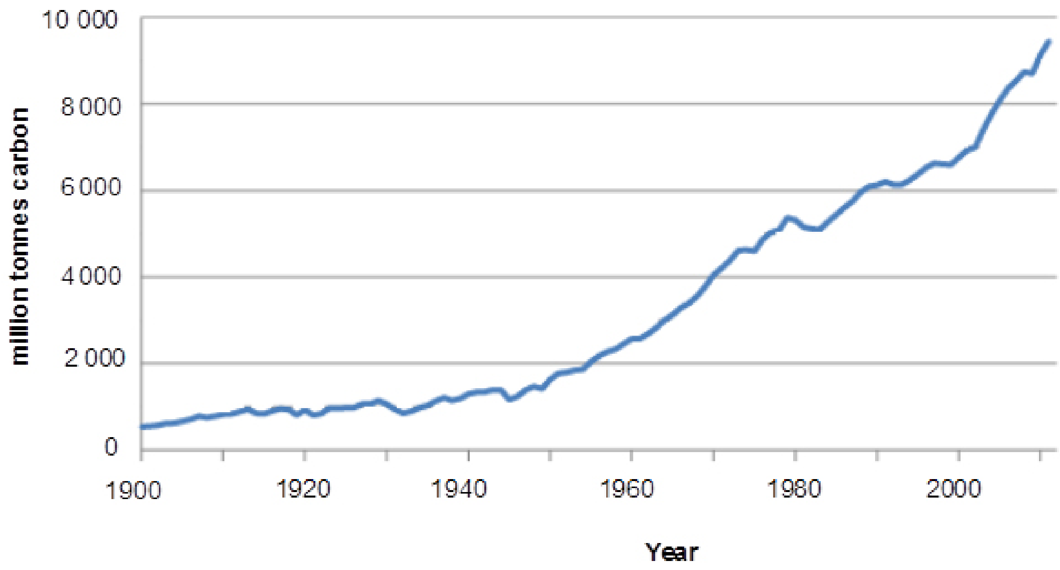
Coal-fired power statio
Paul Glendell / Alamy Stock Photo

Burning fossil fuels such as coal, oil and natural gas results in carbon from the fossil fuels being released into the atmosphere as CO_2.

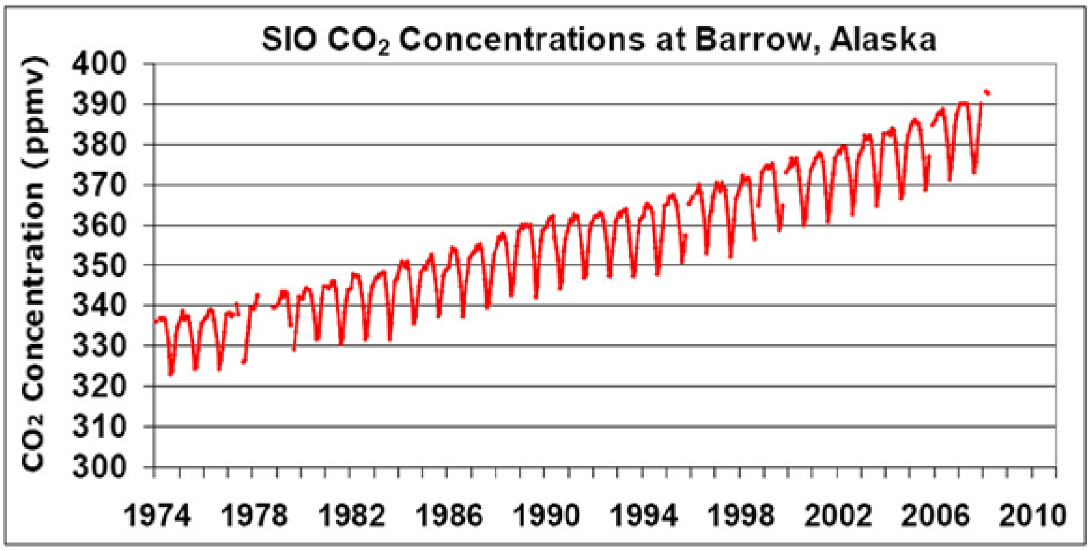
This is the most significant man-made contributor to global carbon dioxide emissions

Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO_2 emissions have increased by about 90%.

The graph on the following page shows the annual emissions of carbon dioxide into the atmosphere as a result of burning fossil fuels.



As a result of man's activity, the carbon dioxide concentration in the atmosphere is increasing. The graph below is based upon readings taken at Barlow, Alaska. Notice there are seasonal variations in carbon dioxide levels.



Does this matter?

There is a general consensus between most scientists that increased carbon dioxide levels in the atmosphere are responsible for global warming and climate change.

To understand this we need to consider the greenhouse effect.

The greenhouse effect

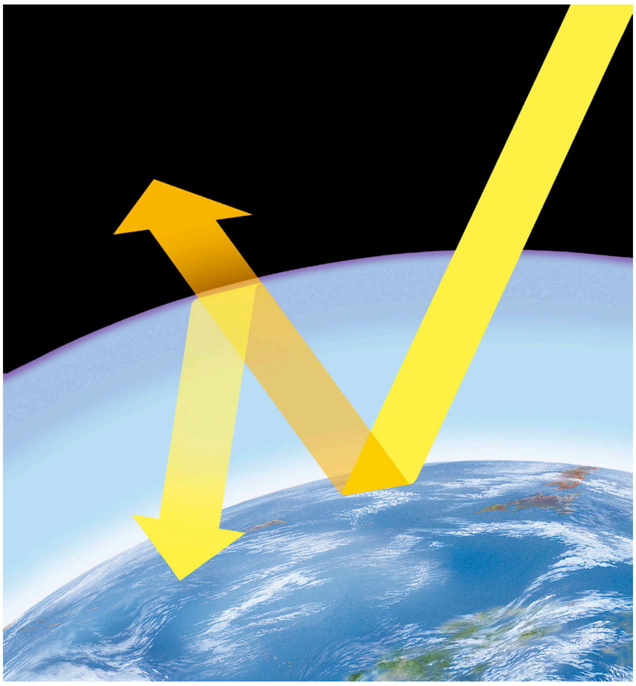
The **greenhouse effect** is a **natural** process by which the atmosphere traps some of the Sun's energy, warming the Earth enough to support life.

Without the greenhouse effect, the Earth would be a very much colder place (about 30°C cooler). The greenhouse effect allows for liquid water on the Earth's surface and helps stabilise conditions for life.

The Earth's atmosphere behaves as a greenhouse. Certain gases (e.g. water vapour, methane and carbon dioxide) stop heat radiating into space from the Earth and thereby keep the Earth warmer than it otherwise would be. This is called the greenhouse effect.

The greenhouse effect is explained below:

1. Most electromagnetic radiation from the Sun passes through the Earth's atmosphere but some is reflected
2. The Earth's surface absorbs electromagnetic radiation with short wavelengths and so warms up.
3. Heat is radiated away from the Earth's surface as longer wavelength infrared radiation.
4. Some of this infrared radiation is absorbed by greenhouse gases in the atmosphere and re-emitted in all directions. Some of the re-emitted radiation is trapped in the Earth's atmosphere and some escapes into space.



Greenhouse effect
Gary Hincks / Science Photo Library

SOMETHING TO WATCH

Watch a video explaining the greenhouse effect.

https://www.youtube.com/watch?v=ZzCA60WnoMk

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

Global warming and climate change

Global warming is the term used to describe the gradual increase in the mean temperature of the Earth's atmosphere and its oceans, a change that is believed to be permanently changing the Earth's climate.

Carbon dioxide levels in the atmosphere are increasing. Many scientists believe that the increased **carbon dioxide concentration** is responsible for global warming.

They believe that the extra carbon dioxide is trapping even more heat in the Earth's atmosphere and is strengthening the greenhouse effect.

Changes in the climate, as a result of **global warming** may:

- make it impossible to grow certain food crops in some regions
- cause melting of polar ice caps which may lead to rising sea levels and the flooding of low-lying land
- make extreme weather events more likely since there is more energy in the hotter atmosphere

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

The graphs below show that the **mean** annual global temperature has increased as the carbon dioxide concentration has increased.

The increase in temperature from long term averages is known as the **global temperature anomaly.** It is probable that the increase in global temperature is a result of carbon dioxide increases.

Computer models appear to back this up; climate predictions from these models show similar changes to what actually occurs when the amount of carbon dioxide is altered in the models.

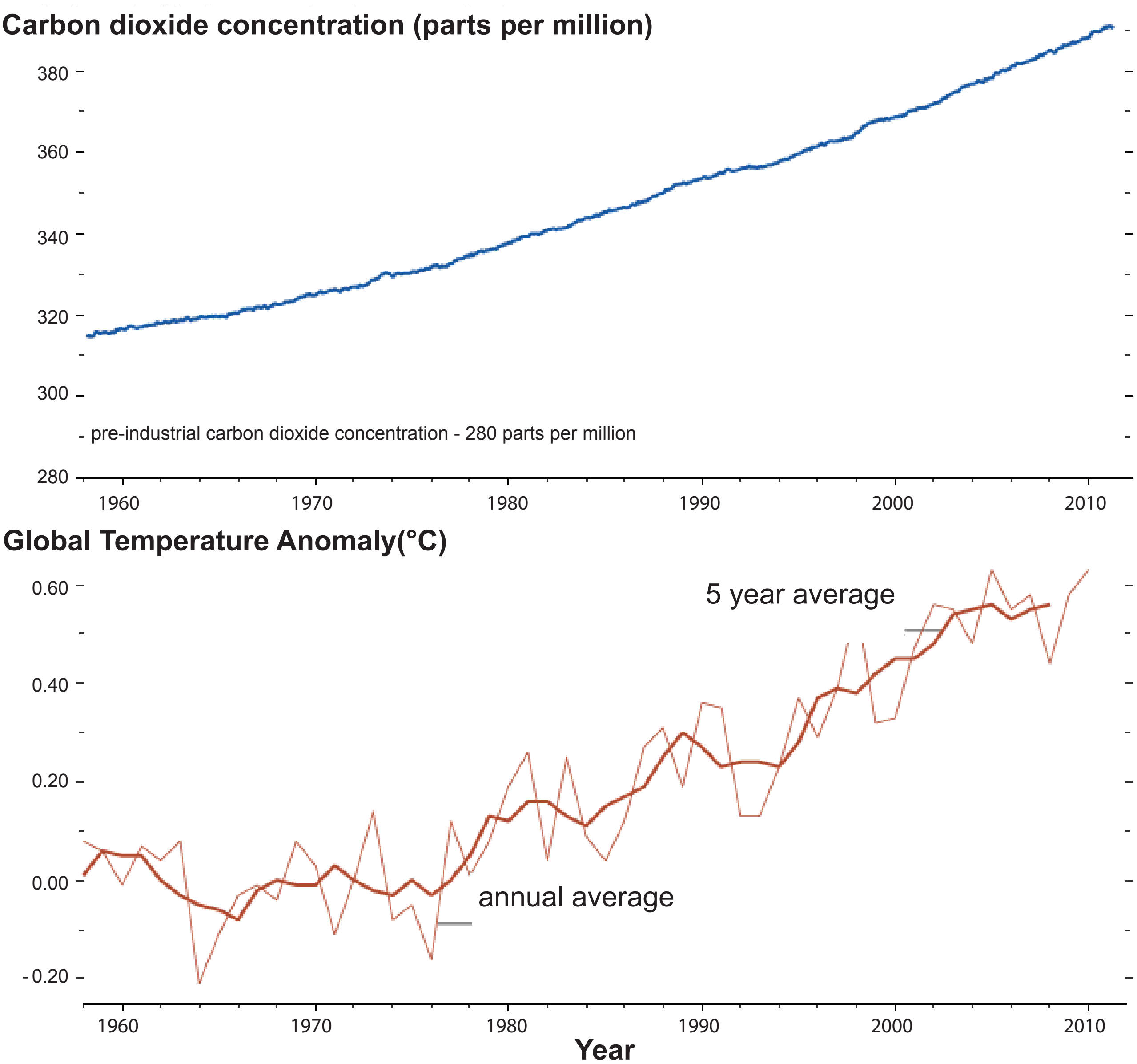


Diagram from http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

Other factors affecting global warming

There are a small number of scientists who agree that global warming is taking place, but do not agree that carbon dioxide levels are to blame.
A factor that may affect the mean temperature of the atmosphere is the amount of energy given out by the Sun. Although the solar output from the Sun is extremely stable it is possible that even very small changes may have an effect on the Earth's climate. Apart from the 11 year sunspot cycle, there appear to be longer cycles in solar output (200 years, 2 400 years) which may affect the Earth.
At present, solar variations remain a controversial mechanism of climate change.

Solutions to global warming

What can we do?

- Decrease our fossil fuel use.
- Switch to low carbon energy sources, for example, nuclear, wind, solar, tidal power.
- Use carbon capture technologies:

  Carbon capture means that carbon dioxide emissions are trapped and stored before they get into the atmosphere.

Puzzle piece
SilverV / gettyimages

  Thus if we burn methane to generate electricity, we capture and store the carbon dioxide instead of releasing it into the atmosphere.

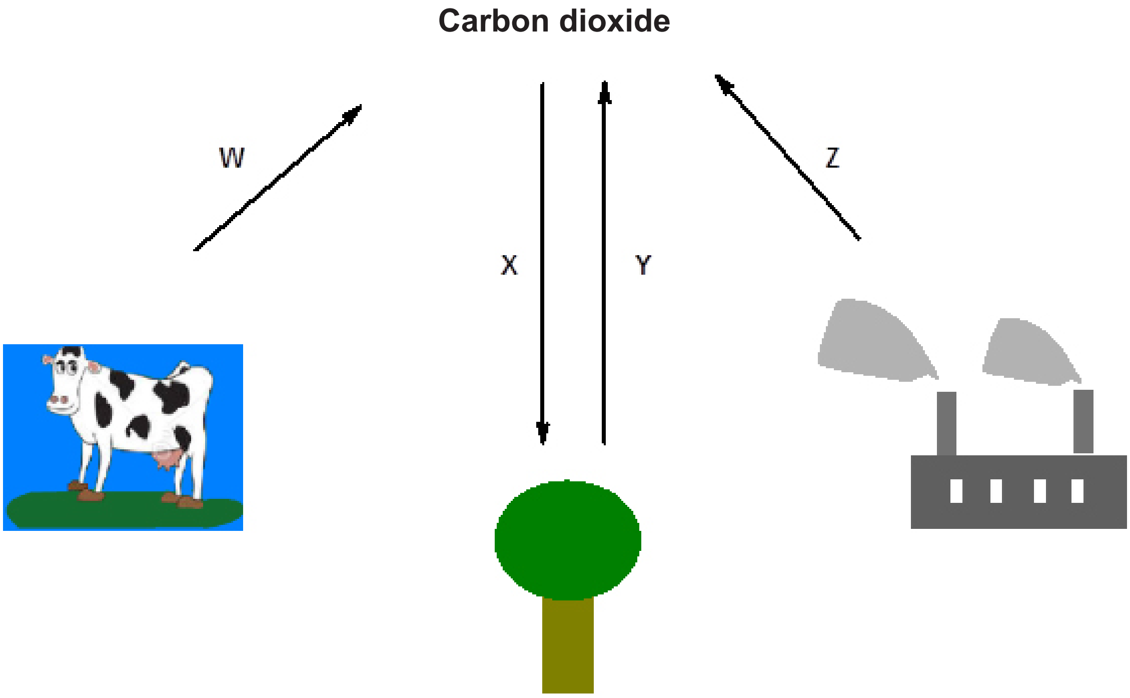
- Recycle

  Recycling generally involves using less energy than obtaining new resources.

- Use cars less and public transport more

TEST YOURSELF

1. Select the correct labels for the processes W, X, Y and Z that remove or add carbon dioxide to the atmosphere.



(a) **Label W**: **A** respiration **B** photosynthesis **C** combustion
(b) **Label X:** **A** respiration **B** photosynthesis **C** combustion
(c) **Label Y:** **A** respiration **B** photosynthesis **C** combustion
(d) **Label Z:** **A** respiration **B** photosynthesis **C** combustion

2. **Two** gases that cause the greenhouse effect are:

A carbon dioxide and methane
B carbon dioxide and nitrogen
C water and nitrogen

3. Changes to the Earth's climate may:

A increase the number of tsunamis and earthquakes
B cause sea levels to rise
C damage the ozone layer

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

NUTRIENT CYCLES

Nutrient cycles can be thought of as nature's recycling system.

Ecosystems are interconnected systems where matter and energy flows and is exchanged as organisms feed, digest, and move about. As we have seen, the carbon cycle describes how carbon is extracted from the atmosphere and flows through the food chain until it is returned to the atmosphere as carbon dioxide.

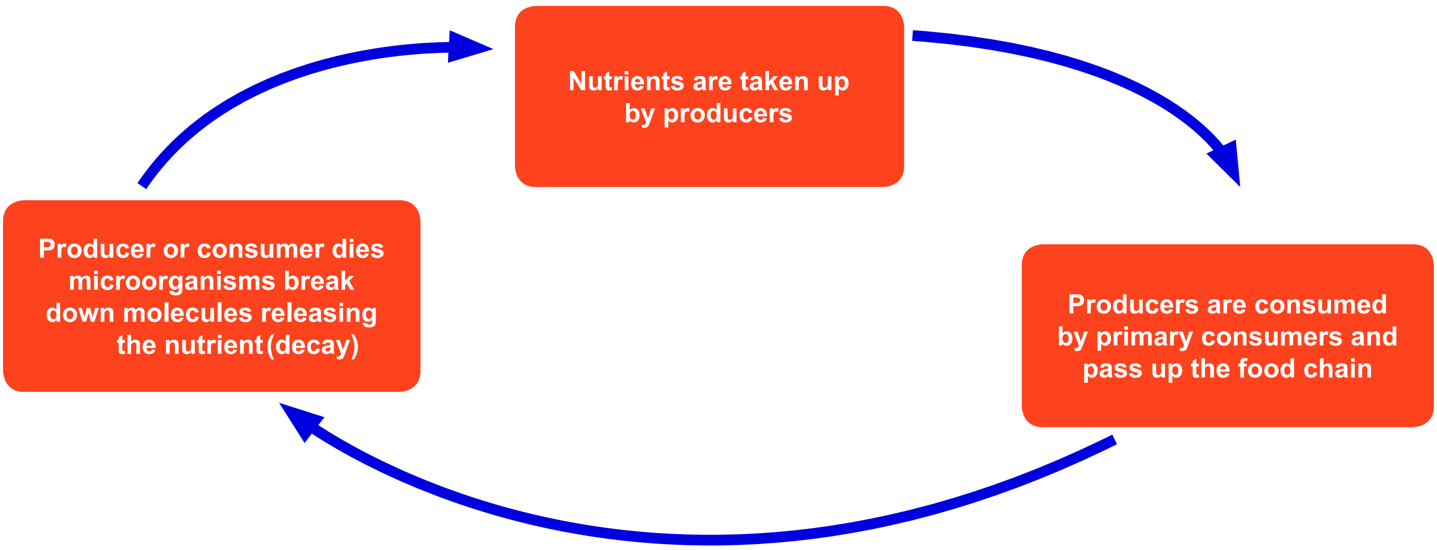
The carbon cycle is an example of nutrient cycling. As we have seen, the carbon cycle describes the extraction of carbon from the atmosphere by plants using photosynthesis, its movement through the food chain and its return to the atmosphere.

Similar mineral cycles can be described for valuable minerals such as nitrogen, phosphorus and oxygen. All these are necessary for life. In fact, nutrient cycling is one of the most important processes that occur in an ecosystem.

Recycling
Science Photo Library / Alamy Stock Photo

Nutrient cycles describe the use, movement, and recycling of nutrients in the environment.

The basic elements of a nutrient cycle can be summed up in a simple diagram.



In a stable ecosystem, the processes which remove materials are balanced by processes which return materials.

Our planet (Unit 1.3)

Transfer and recycling of nutrients (specification 1.3.3)

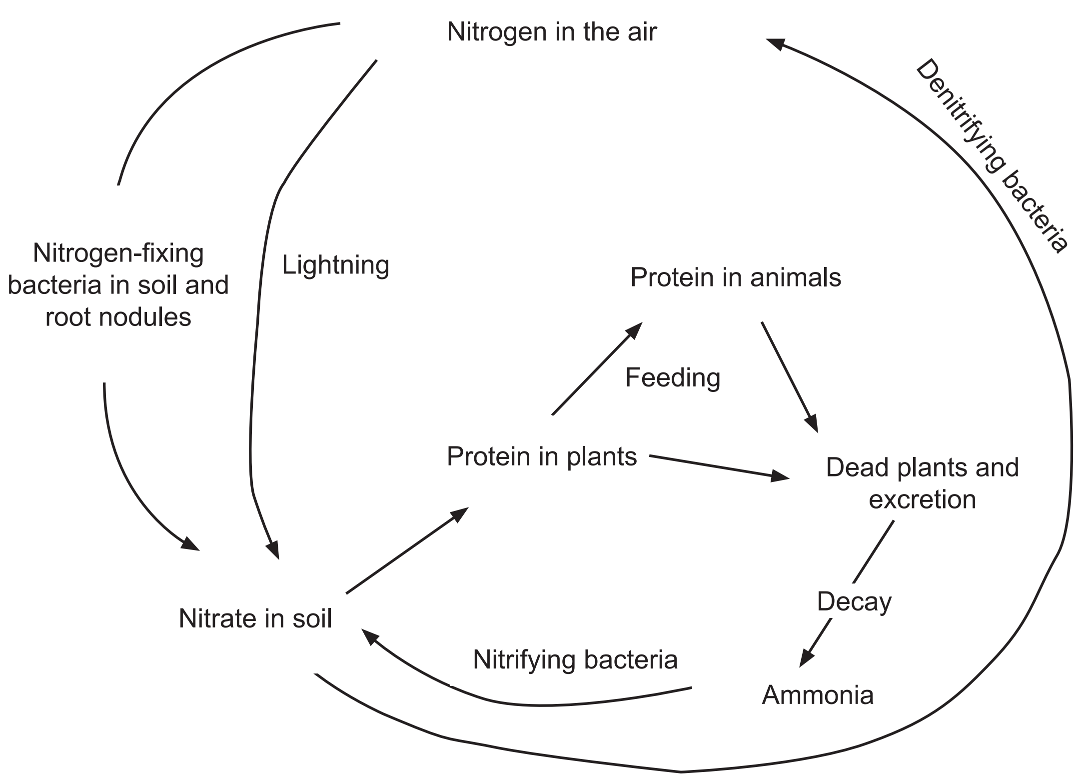
Nitrogen cycle

Brief overview

An example of a nutrient that is recycled is nitrogen. Plants and animals need nitrogen for proteins to enable growth. This element is released as ammonia when organisms die and decay as a result of the action of microorganisms. Ammonia is converted into nitrate and released into the soil which can then be used by other organisms e.g. plants.

Foundation tier: You do NOT need to know about the details of the nitrogen cycle that follow (the cycle or key points).

In more detail



The key points

- Nitrogen gas **cannot** be used directly by plants or animals.
- Nitrogen-fixing bacteria living in root nodules of **legume** plants **or** the soil fix nitrogen gas int nitrates. The action of lightning can also convert some atmospheric nitrogen into nitrates.
- Decomposers (bacteria and fungi) break down dead animals and plants converting the proteins and urea into ammonia.
- **Nitrifying bacteria** convert this ammonia to nitrates.
- Plants absorb nitrates from the soil.
- Primary consumers eat producers and digest the plant proteins for their own use (to form new proteins).
- Nitrogen is passed up the food chain from one trophic level to the next.
- **Denitrifying bacteria** covert nitrates to nitrogen gas. Denitrifying bacteria prefer to live in waterlogged or unploughed soil.

Water-logged fields lose nitrogen by leaching and due to the action of denitrifying bacteria.

Flooded fiel
watcherfox / gettyimages

Factors affecting decomposition processes

The table below summarises a number of factors that affect the action of microorganisms in decomposition reactions (e.g. compositing and land fill sites)

Factor	Comment
temperature	• high temperatures prevent decay action of enzymes as the proteins are denatured • decomposers killed • low temperatures slow decay • rate of growth and reproduction of decomposers reduced
oxygen	• oxygen is needed for respiration by decomposers
water	water is needed: • for transport • to support reactions inside decomposers
pH	• compost microorganisms operate best within a pH range of 5.5 - 8
Heavy metals	• heavy metals may slow decomposition rates due to toxicity of these elements towards microorganisms

Compost heap

Organics image library / Alamy Stock Photo

Compost heaps need a good supply of oxygen for microorganisms to respire.
Decomposition is fastest in the temperature range of 40-60°C.
Most species of microorganisms cannot survive at temperatures above 60-65°C and so decomposition is prevented at higher temperatures.

PRACTICE QUESTIONS

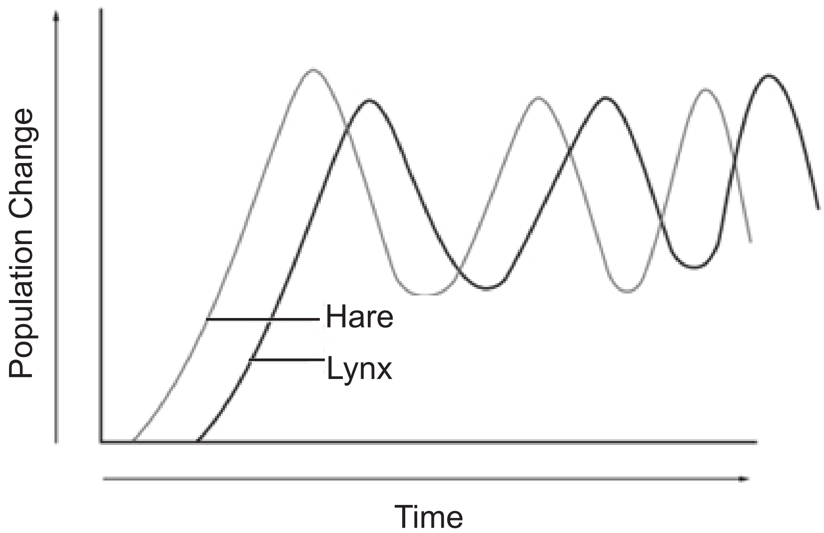
1. In the natural habitat, the lynx is a predator of the snowshoe hare.

(a) State one way in which the hare is adapted to its environment. [1]

....

....

(b) The population of lynx and hares changes in the pattern shown in the graph.



Explain why the population change of lynx lags behind that of the hare. [3]

....

....

....

....

....

PRACTICE QUESTIONS

2. The table shows the energy budget for a cow grazing on grass.

Input energy (food) (kJ)	Losses (kJ)		Retained energy (kJ)
	heat	undigested food waste	
2 500	850	1 520	…………….

(a) Calculate the retained energy for the cow. **Write your answer in the table**. [1]

(b) The energy conversion efficiency (ECE) is the percentage (%) of input energy retained within the cow.

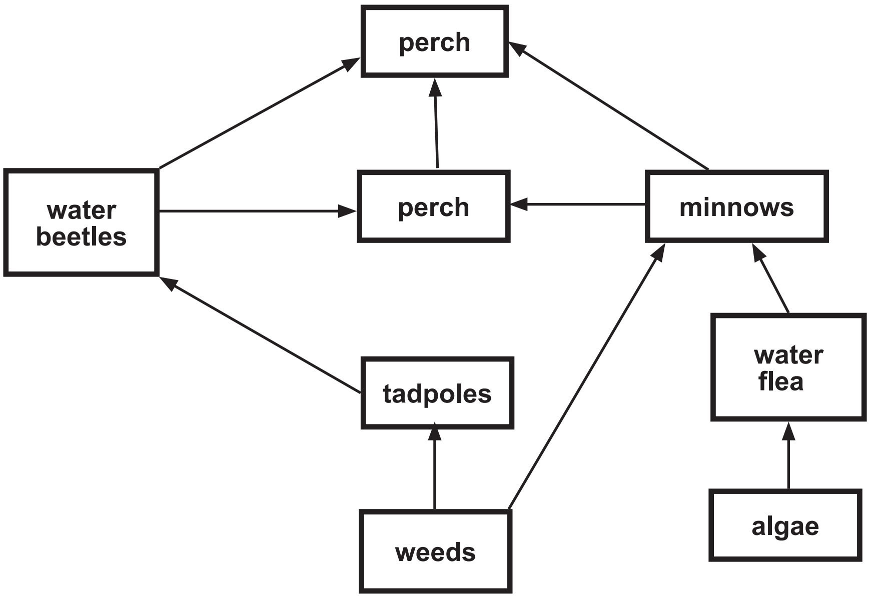
Calculate the ECE for the cow. [2]

ECE = ……………%

PRACTICE QUESTIONS

3. (a) (i) Name the source of energy for a food web. [1]

....



(ii) Name one secondary consumer from the food web above. [1]

(iii) Draw one food chain from the web that includes four living things and ending with the perch. [2]

(b) A warden regularly removes lilies from the surface of the pond.
Explain why this is necessary. [2]

....

....

(c) The warden notices the water fleas are disappearing from the pond.
Explain how this will affect the food web. [3]

....

....

....

PRACTICE QUESTIONS

4. Denitrifying bacteria prefer to live in waterlogged ground. Denitrification leads to the gaseous loss of nitrous oxide (N_2O) into the atmosphere, which is a major greenhouse gas.

Flooded fiel
driftlessstudio / gettyimages

Using this information, answer the following questions.

(a) Give one environmental advantage of improving drainage of waterlogged ground. [1]

……………………………………………………………………………………………

……………………………………………………………………………………………

(b) Explain one economic benefit and one environmental advantage of improving drainage of waterlogged ground. [2]

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Our planet (Unit 1.3)

TEST YOURSELF - ANSWERS FOR UNIT 1.3

Using electromagnetic radiation to explore the universe

1. **A** increasing wavelength **B** microwaves **C** infrared **D** X-rays

   E gamma waves **F** increasing frequency

2. B
3. B
4. A
5. C
6. B

Our Solar System

1. A
2. D
3. B
4. Io – most volcanically active body in the solar system with hundreds of volcanoes
   Phobos - the larger and innermost of the two natural satellites of Mars
   Titan - only moon in the solar system with clouds and a thick atmosphere

Classification of organism

1. C
2. B
3. C

Adaptation to the environment

1. C
2. a) A b) C
3. B

Our planet (Unit 1.3)

TEST YOURSELF - ANSWERS FOR UNIT 1.3

Chains, webs and pyramids

1. plants, level 1, primary, 3
2. A
3. B

Interdependency of organisms

1. C
2. predator, increased, predator

The carbon cycle

1. (a) A (b) B (c) A (d) C
2. A
3. B

Science in the Modern World (Unit 1)

Protecting our environment (Unit 1.4)

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

ENVIRONMENT UNDER THREAT

The environment and biodiversity is changing due to the impact of human activity on the environment. Human activity includes building homes, factories, shops or roads, mining resources from the ground or disposing of the waste, growing food, using energy resources and much more. All these activities affect the environment around us. This leaves us with questions to answer.

How do our unwanted products affect the world around us? How can we live more sustainably? How can we treat our waste products to improve safety? What methods can be used to maintain biodiversity?
Science can help us answer these important questions.

Habitat

One of the great threats to biodiversity is loss of habitat. We first need to remind ourselves of what is meant by the term habitat.

A **habitat** is a place where an organism or a community of organisms live.

Examples of habitats:

- a grove of trees
- grasslands
- hedgerows
- rainforest
- a pond
- a bog
- rivers and streams
- a host organism inhabited by parasites

If we destroy a habitat, animals that are adapted to that habitat will struggle to survive or become extinct. This results in a loss of biodiversity.
Habitat loss is probably the main reason why species become extinct.

Giraffe in Savanna
Anna Omelchenko / Alamy Stock Photo

The following would be examples of habitat destruction:

- clearing forests for farmland
- filling in wetlands to build house
- mining or quarrying
- poisoning land with pollutants from mine waste (e.g. Parys Mountain where copper mining in the 18th century destroyed the original natural habitat).

Parys Mountain copper mine
Jeff Morgan 16 / Alamy Stock Photo

Protecting habitat

If we can protect the natural habitat, then the organisms that live in that habitat have an opportunity to survive. This can be achieved by creating National Parks, nature reserves or making Sites of Special Scientific Interest

One issue related to habitat loss is fragmentation of habitat. This happens when a habitat that was once continuous is split up into smaller pieces. This has big impacts on animals that can't move between patches of suitable habitat.

Fragmented habitats make it harder for animals to find food, and harder to find a mate becaus they get isolated from each other. This reduces the chances of survival.

One way of overcoming this problem is to create **land corridors** connecting the smaller reserves together. This allows organisms to move between habitats and improves their chance of survival. It also helps preserve the genetic diversity of the organisms.

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Conservation and sustainability

Conservation

Protecting the habitat is one way of preserving biodiversity. It shows us the need to act in a responsible way towards the environment. Protecting habitat is part of conservation.

Conservation is the protection, preservation, management, or restoration of wildlife and of natural resources such as forests, soil, and water.

Examples of different methods of conservation are summarised below:

- protecting habitats by creating Sites of Special Scientific Interest or National Park
- making laws to protect endangered species and control international trade
- captive breeding programmes
- The goal of most captive breeding programs for endangered species is to establish captive populations that are large enough to be stable and genetically healthy.
- creating a genetic bank (a seed bank or sperm bank)

The purpose of a **genetic bank** is to store genetic material for the future.

For example, a **seed bank** stores seeds to preserve genetic diversity.

A **sperm bank** is a similar concept applied to preserving genetic diversity in animals.

The mountain gorilla is an example of an animal that is critically endangered and needs protection.

Mountain gorillas
imageBROKER / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Sustainability

We also need to act in a responsible way towards the environment when we use natural resources. We have a duty to act in a thoughtful way so that future generations will also be able to enjoy the rich diversity of life on Earth as well as having sufficient resources to live. This means we need to live sustainably. This is particularly important as the world's population is growing and there is a greater demand on resources.

Sustainability means that we provide for our needs **without** using up the resources and damaging the environment.

To act sustainably we need to think carefully about the consequences of:

1. using natural resources.
   This may require us to change the way we do things. For example,
   - quotas are placed on fishing so that fish stocks are not completely used
   - trees may be replanted if some woodland is removed
   - recycling schemes are put in place so reducing our need to find new raw materials

2. changing the way we use land.
   This requires us to take into account the impact of, for example, housing developments or road building on the environment.

- In England and Wales all new development work requires environmental scientists to complete an **Environmental Impact Assessment.**

  This involves scientists collecting data on the environment where the proposed development is to take place and assessing how the environment, including endangered species in that environment, will be affected. The assessment is used to decide whether the work should go ahead, be refused or modified to reduce the e fect on wildlife.

Housing development
Image Source / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Pollution

Pollution involves the addition of substances to the environment that have a harmful effect on living organisms.

Sometimes we use compounds for a positive purpose but if they get into the wider environment there can be **unintended** consequences.

Adding fertiliser to a field can cause unintended problem
Julian Eales / Alamy Stock Photo

Examples:

Pollutant	Comment
heavy metals	These may get into the environment as a result of mining or incorrectly disposing of waste containing heavy metals. Many heavy metals are toxic and **accumulate** in the food chain (read later about the bioaccumulation of mercury).
fertilisers	Fertilisers are spread on fields to improve crop growth. It is possible that fertilisers may be washed off fields into waterways where they may cause **eutrophication.**
pesticides	Pesticides are used in agriculture to kill pests that otherwise destroy crops. These may remain in the soil for a long time or be washed off into waterways. Some pesticides have been linked with environmental damage (read later about the bioaccumulation of DDT).
sewage	If sewage gets into waterways it may also cause **eutrophication**.
waste - plastics	Most plastics are not biodegradable. This means they can persist in the environment for a very long time. Even our oceans contain large quantities of plastics. This may cause animals to choke if they mistake it for food. The government in Wales introduced charges on carrier bags to help try to **reduce** our use of plastic bags. The use of **bio**degradable plastics also helps **reduce** the long term impact of the plastics on the environment.
waste - household items	Many household items contain toxic chemicals. e.g. • low energy lamps contain mercury; • batteries and mobile phones contain toxic chemicals. These should not be put in general household waste to be buried in a landfill site.

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Sustainability, conservation and waste disposal

Sewage treatment

How do we prevent sewage damaging the environment? This is the role of sewage works.

In sewage treatment works, the **main process** is the breakdown of the waste by the action of **microorganisms** into products which are harmless to the environment.
A wide range of different bacteria are needed to breakdown the different types of material found in sewage.

In sewage treatment works, lots of oxygen is provided by stirring the waste. Oxygen is needed by the bacteria for aerobic respiration. **Aerobic respiration** means that the waste is completely broken down.

Anaerobic respiration would only give a partial breakdown of the waste.
The treatment of sewage means that the water, after treatment, is safe to be discharged back into rivers.

The solid waste left after treatment is completed can be used as a fertiliser for fields.

Sewage treatment - aeration
LOOK Die Bildagentur der Fotografen GmbH / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Household waste disposal

The European Union defines waste as 'any substance or object that the holder discards, intends to discard or is required to discard'. We probably just call it rubbish. Whatever the name, it is a problem. Placing rubbish in landfill sites is not sustainable.

Landfill site UK
Paul Glendell / Alamy Stock Photo

What should we do with our waste? The options are:

- bury it in a landfill site or incinerate
- reuse
- recycle

Burial or incineration is really a last resort. There is a limit to how much material can be put into a landfill site. This is also wasteful since the resources that were used to make the product in the first place are no longer available to future generations.

Reuse

Reuse is often confused with recycling and considered to be the same. However, they actually concern entirely different processes.

Reusing refers to using an object as it is without treatment.
This reduces pollution and waste, thus making it a more sustainable process.

Reuse is preferable to recycling since it generally consumes less energy.

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Recycle

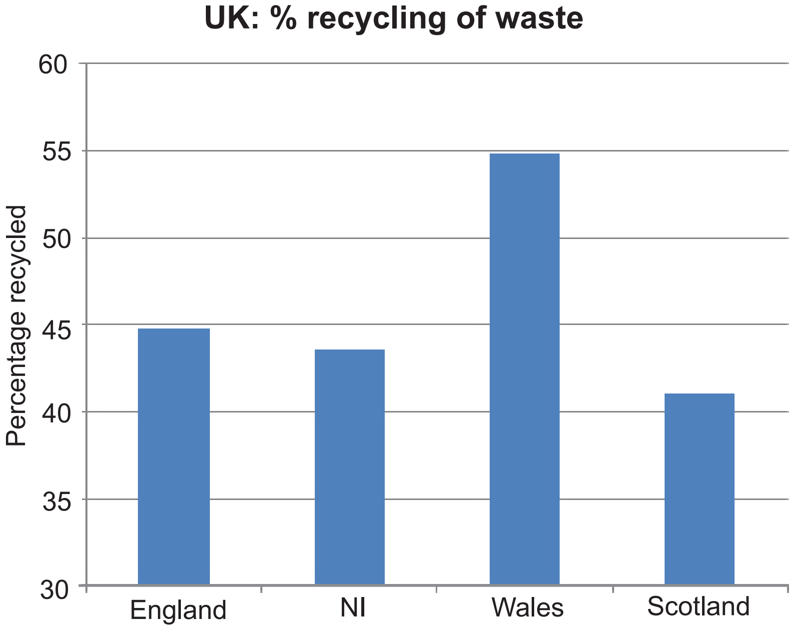
Recycling means turning an item back into raw materials which can be used again, usually to make a completely new product.

Negatively, recycling is an energy consuming procedure.
Positively, recycling:

- means that we bury less material in landfill site
- reduces our need to extract new raw materials from the Earth
- helps improve sustainability and also reduces damage to the environment when we obtain the material.

All Welsh councils have been set the target to recycle 58% of waste by 2016 and the target will eventually rise to 100% by 2050.

In 2015, households in Wales generated 1.3 million tonnes of household waste of which 54.8% was recycled. This was the highest recycling figure in the UK.



Finally what should we as citizens do to be more sustainable?
It can be summed up in three words:

reduce	**reuse**	**recycle**

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

What happens if pollutants get into the environment?

If pollutants get into the environment they can cause serious harm. We will look at just two problems caused by different pollutants in more detail. Obviously, other pollutants can have other environmental effects (e.g. carbon dioxide has been linked with global warming).

Bioaccumulation of toxic compounds

Bioaccumulation is the gradual build up over time of a chemical in a living organism.

These chemicals are then passed up the food chain from one trophic level to the next and often become more concentrated as they do so.

This means animals at the top of the food chain are affected more severely.

This is what happens:

- Small amounts of toxic substances are taken up by producers (plants)
- These plants are eaten by primary consumers
- Primary consumers are eaten by secondary consumers which in turn are eaten by higher level consumers
- At each trophic level of the food chain, the toxins remain in the tissues of the organisms and so the toxin concentration is highest in animals at the top of the food chain.

Example: Minamata disease

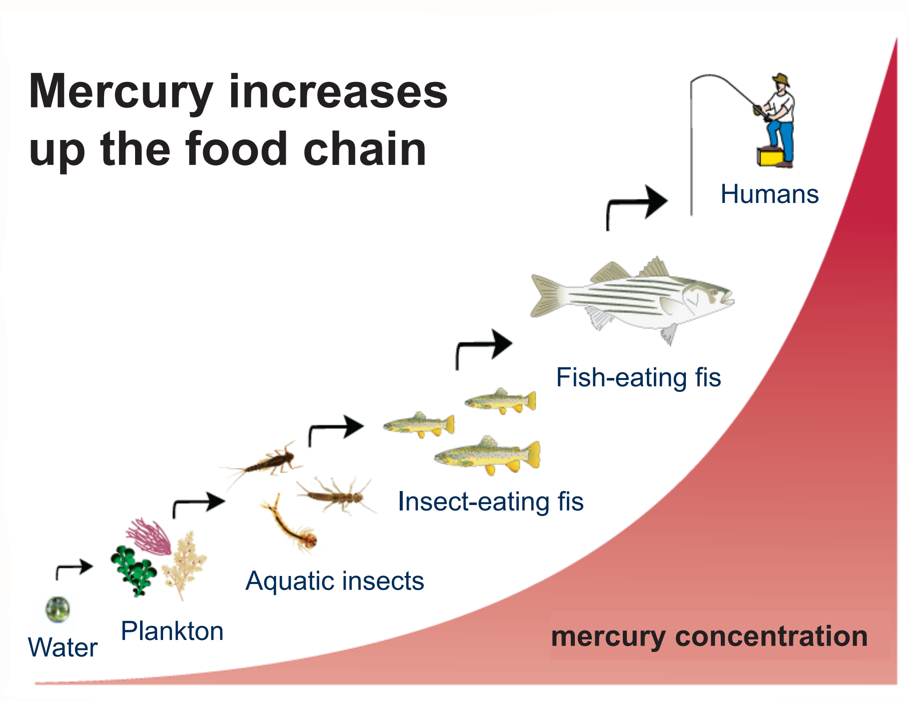
A disease was first noticed in Minamata, Japan in communities which ate shellfish and fish as part of their diet which came to be known as Minamata disease.

Those suffering from it experienced numbness, loss of vision, damage to hearing and speech and muscle weakness. Animals in the community were also affected. The animal effects were severe enough in cats that they came to be named as having “dancing cat fever”.

The cause of the disease was found to be mercury poisoning. Mercury is a heavy metal which accumulates in the food chain.

It was caused by the release of a toxic mercury compound into the sea from a chemical factory. The mercury was taken up by plankton where it accumulated.

Zooplankton consumed the contaminated plankton. The mercury was passed higher up the food chain to higher level consumers, such as shellfish and fish where it concentrated further.



Humans, as the final consumers, ended up consuming fish and shellfish with high mercury concentrations.

Example: DDT

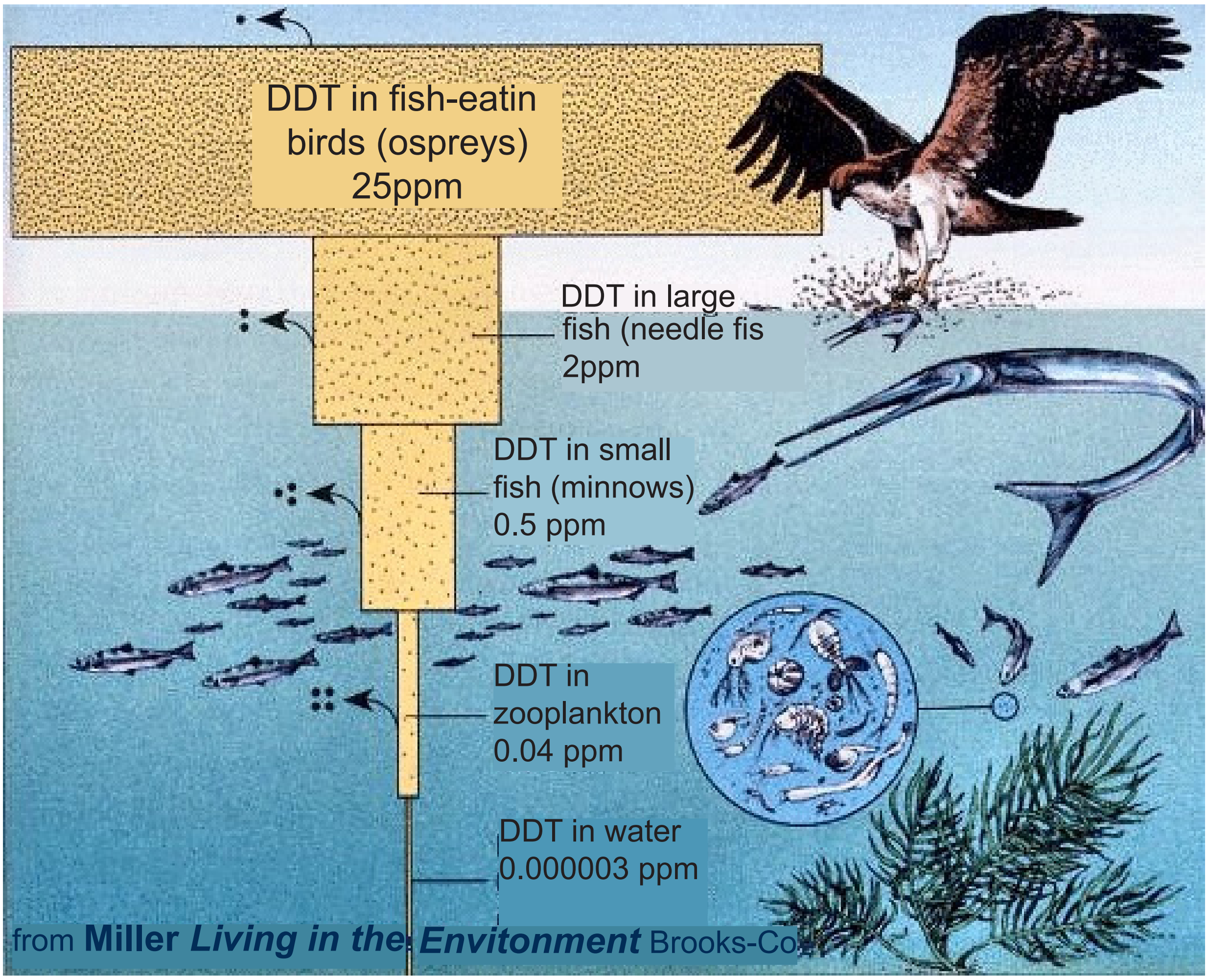
Another example of bioaccumulation is from the use of DDT as an insecticide in the 1950s and 1960s.

DDT is an insecticide that can pass up the food chain from producers to zooplankton to small fish to larger fish and finally to birds of prey, such as the osprey.

It accumulates in the birds of prey, giving them a large concentration of DDT. High concentrations of DDT in birds cause weakness in their eggs so reducing their population.

DDT was used to kill fleas and mosquito
Everett Collection Historical / Alamy Stock Photo

The diagram below shows how the concentrations of DDT magnify through each level of the food chain.



http://www.mhhe.com/biosci/genbio/enger/student/olc/art_quizzes/genbiomedia/0414.jpg

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Eutrophication of rivers and lakes

Fertilisers contain high levels of nitrates and phosphates to encourage plant growth. If fertilisers are washed into streams or lakes they can cause serious environmental harm in a process known as **eutrophication.**

1. High levels of nitrates and phosphates from fertilisers encourage the growth of photosynthesisers such as plants and algae which forms a bloom over the surface (algal bloom).
2. Plants under the algal bloom die because of a lack of sunlight.
3. When the plants and algae die, they decompose by the action of microorganisms.
4. The microorganisms use oxygen from the water for respiration, so reducing the concentration of dissolved oxygen in the water.
5. The oxygen levels fall so low that fish can no longer live.

Sewage has the **same** effect as fertilisers and can also cause eutrophication.

Fish death due to eutrophication
blickwinkel / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Monitoring our environment

Living Indicators

Pollution levels can be measured directly. The presence or absence of certain living organisms can also act as an indicator of the amount of pollution.

An indicator species is a species whose abundance gives us a measure of the health of the ecosystem.

Examples

1. Lichens

Lichens grow in exposed places such as rocks or tree bark. They need to be very good at absorbing water and nutrients to grow there. Rainwater contains just enough nutrients to keep them alive.

Air pollutants dissolved in rainwater, especially sulfur dioxide, can damage lichens and prevent them from growing.

This makes lichens natural indicators of air pollution.

Different lichens can tolerate different levels of pollution. For example,

- bushy lichens need clean air
- leafy lichens can survive a small amount of air pollution
- crusty lichens can survive in more polluted air

A variety of lichens growing on a tree in Scotland
MichaelGrant / Alamy Stock Photo

If no lichens grow in an area then that is a sign that the place is heavily polluted.

2. Invertebrate animals can be used to monitor water pollution

Many aquatic invertebrate animals cannot survive in polluted water, so their presence or absence indicates the extent to which a body of water is polluted.

Examples of indicator species for levels of water pollution are given in the table below.

Factor	Indicator species
very high	sludgeworm, rat-tailed maggot
high	water louse
low	freshwater shrimp
clean	mayfly larv

The mayfly larva is only found in clean water
blickwinkel / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

Non-living Indicators

Non-living indicators are physical measurements (e.g. oxygen concentration) which tell us something about the health of an ecosystem.

Examples of non-living indictors are:

- temperature
- pH
- oxygen concentration

All these physical parameters tell us something about the health of an environment. In most cases these parameters are most easily measured using a digital probe.

Measuring oxygen using digital oxygen probe
Martin Shields / Alamy Stock Photo

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

TEST YOURSELF

1. Select the correct word (or words) in the brackets that is/are correct:
High levels of fertiliser in a river can lead to (**eutrophication / bioaccumulation**).
This process is described below.

1. High levels of (**pesticides / nitrates / acids**) encourage the growth of photosynthesisers such as plants and algae.
2. Plants that are under the algal bloom die because of a lack of sunlight.
3. When the plants and algae die, they decompose by the action of microorganisms which use (**carbon dioxide / nitrogen / oxygen**) when they (**photosynthesise / respire)**.
4. The fish can no longer live because **carbon dioxide / nitrogen / oxygen**) levels are too low.

2. Two examples of living indicators are:

A lichens and oxygen concentration
B pH and invertebrates
C lichens and invertebrates
D pH and oxygen concentration

3. Two examples of non-living indicators are:

A lichens and oxygen concentration
B pH and invertebrates
C lichens and invertebrates
D pH and oxygen concentration

4. It is important that we use resources sustainably. Select the correct statement from below.

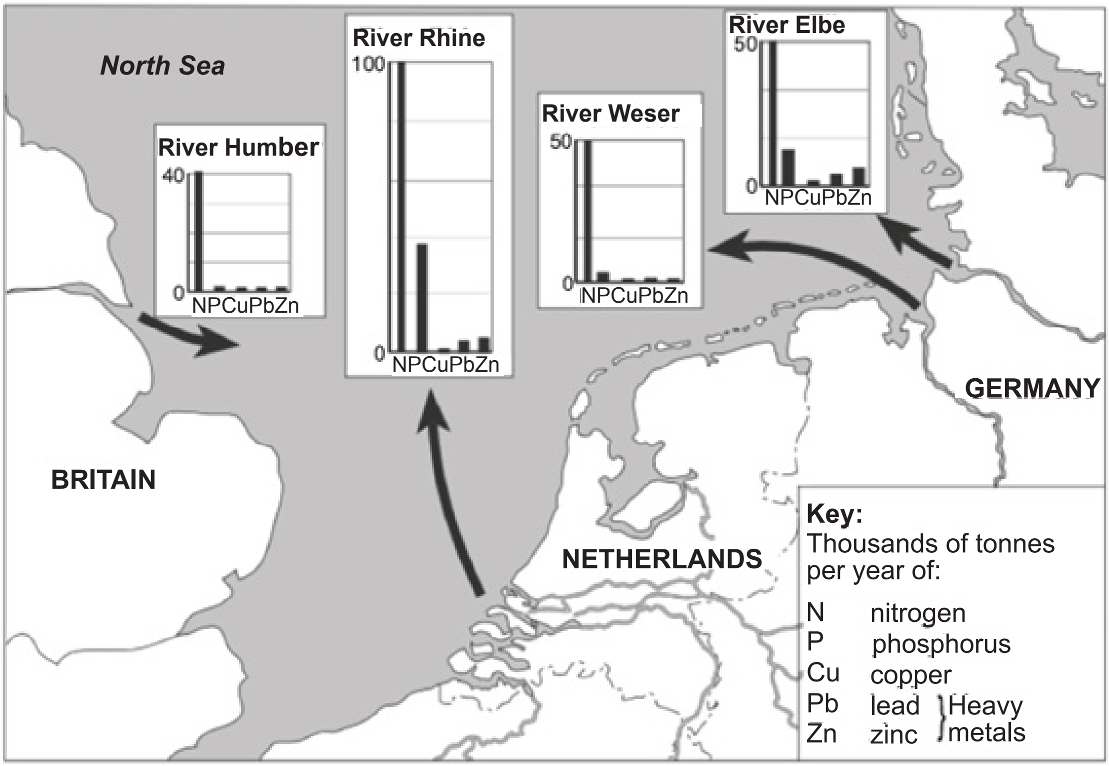
A Recycling is considered sustainable even though it requires the use of energy
B Recycling is sustainable because it does not require the use of energy
C Recycling waste refers to using an object without treatment

Protecting our environment (Unit 1.4)

Protecting our environment (specification 1.4)

PRACTICE QUESTIONS

1. Over 80% of sea pollution comes from land-based activities. Rivers are one common path of entry of pollution into the sea. The map shows the main pollution levels in some rivers that enter the North Sea.



(a) Use the information above to answer this question.

(i) State one way farming adds to water pollution. [1]

……………………………………………………………………………………

(ii) State one way industry adds to water pollution. [1]

……………………………………………………………………………………

(b) Explain why the lowest concentration of oxygen is found at the mouth of the river Rhine. Use the information above to give one reason why. [2]

……………………………………………………………………………………

……………………………………………………………………………………

PRACTICE QUESTIONS

(c) It is observed that many fish-eating birds have been found dead near the mouth of the rivers Elbe and Rhine.

(i) Use the information above to give one reason why. [1]

……………………………………………………………………………………………

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(ii) Explain why dead birds are found rather than dead fish. [2]

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TEST YOURSELF - ANSWERS FOR UNIT 1.4

Environment under threat

1. eutrophication, nitrates, oxygen, respire, oxygen
2. C
3. D
4. A

Underpinning energy concepts

1. **(i)** Power is the rate of energy transfer/a measure of how quickly energy is transferred

Also accept: power = energy transferred/time **1**

(ii) **I.** Units used (kWh) = power(kW) × time (h) (1)
= (0.030 × 21) + (0.045 × 3) (1)
=0.765 kWh (2)

II. Difference = 1.080 – 0.765 = 0.315 (kWh) (1)
In year 365 × 0.315 = 115 (kWh) (1)
Unnecessary mass CO_2 = 114.98 × 0.5246 (1)
= 60.3 kg (1) (Unit must be included to be awarded mark) **4**

GENERATING ELECTRICITY

1.	(a)		Step-down transformer - 1 mark
	(b)	(i)	700 [MJ] 1 mark
		(ii)	lost as heat 1 mark
		(iii)	equation (1) correct subs of 1000 & 300 (1) 30[%] (1) 2 marks

2	(a)	Links power stations, to consumers/transfer energy to greatest need	2
	(b)	WIND: renewable, no air pollution, low running costs, unreliable, unsightly NUCLEAR: no air pollution, radioactive (waste), leaks, terrorists, reliable, non-renewable	6
	(c)	Rearranging, subs, answer 1.5 x 106V/1.5MV (90 used lose a mark unless answer given in MV)	3

MAKING USE OF ENERGY

1.	(a)	(i)	Useful output energy, 2.5% of input energy	2
		(ii)	FL - useful output energy = 25 J, CFL – 120 J, difference = 95 J	2
	(b)	(i)	0.02 × 12 000, = 240 (kWh)	2
		(ii)	1 200	1
		(iii)	1 200 - 240/960, 960 × 12, = 11 520p or £115.20 (No. and unit required for third mark)	3

BUILDING ELECTRIC CIRCUITS

1.	(a)	(i)	Current increases as voltage increases in both wire and bulb (1) They are proportional to each other for the wire (1) The rate of increase reduces with the bulb (1)
		(ii)	1.5 V
		(iii)	Current read from graph = 0.3 A (1) Subs 1.5/0.3 (1) = 5 Ω (1)
	(b)		1.0 V read from graph (1) 0.5 V read from graph (1) so total voltage = 1.5 V (1)

ATOMIC STRUCTURE

1.	(a)	(i)	all points plotted correctly (2) any 4 plotted correctly (1) tolerance ± ½ square	3
			line of 'best fit (1) ***drawn with a ruler judgement by eye***	
	(b)	(i)	65 ±1 ***i.e. anywhere from 64-66 °C***	1
		(ii)	19 ±1 ***i.e. anywhere from 18-20 g per 100g of water***	1

RESOURCES FROM OUR PLANET

1. **(a)** Melting point: 98 °C and Boiling point: 890 °C **1 mark**

(b) $2Na + Cl_2 \rightarrow 2NaCl$ **1 mark**

OBTAINING RAW MATERIALS

1. (a)	(i)		carbon and hydrogen (both needed)	1
	(ii)	I	heated / vaporised / boiled	1
		II	condensed / cool down	1
	(iii)		fractional distillation	1

2.	(a)	Iron oxide (1) element (1) $CaCO_3$ (1)	3

1. (a)	(i)	All points correct (2) four points correct (1) join points with line correctly (1)	3
	(ii)	25 cm^3	1
(b)		NaCl	1
(c)		Repeat test without indicator stop adding sodium hydroxide at pH 7 / add only 25 cm3 sodium hydroxide evaporate off (excess) water	3

2.	Indicative content: a description of the reaction between the carbonate and the acid – apparatus named, effervescence, exothermic, the formation of blue coloured copper sulfate solution and the addition of excess of the copper carbonate. The removal of the excess copper carbonate by filtration. Obtaining the crystals by evaporation. Either allowing the solution to evaporate at room temperature or by heating the solution and allowing the remaining solution to evaporate naturally to dryness. Credit to be given for word/symbol equation. **5 – 6 marks:** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks:** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks:** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks:** The candidate does not make any attempt or give a relevant answer worthy of credit.	6

Our Planet (Unit 1.3)

PRACTICE QUESTIONS - ANSWERS FOR UNIT 1

Our place in the universe

1.	**(a)**	(i)	Ticks in boxes 1, 4 and 5	3
		(ii)	Values within the range -70 to -120 °C	1
	(b)	(i)	explosion	1
		(ii)	expand	1
		(iii)	million	1

World of life

1.	(a)		(Physical) change (in organism) (1), to improve survival/feature/ trait/characteristic/that helps an organism to survive (1)	2
	(b)		Mistaken for poisonous snake (1), predators avoid it (1).	2

Interdependency of organisms

1	(a)		Camouflage/blend in	1

	(b)		If the population of prey increases, there will be more food so predator population will increase. As the population of predators increases more food is needed so eventually the population of prey will decrease. Less food for the predators so their population falls again Three from the above. Must be correctly and coherently connected points to get 3 marks.	3
2.	(a)		130	1
	(b)		130/2 500 × 100 (1) 5.2 (1)	2
3.	(a)	(i)	Sun	1
		(ii)	Water beetles/perch/minnows	1
		(iii)	Weeds → tadpoles → beetles → perch **OR** Algae → fleas → minnows → perc (3 ending with perch (1); 4 no perch (1)	2
	(b)		Light not blocked, can pass to weeds	2
	(c)		Affects minnows, decreases, algae increases/pike decrease/perch decrease	3
4.	(a)		Increased nitrogen fixing bacteria /nitrogen fixation less denitrification.	1

	(b)		Economic-greater crop yield Environmental – no need to add fertilizer/manure therefore preventing eutrophication.	2

Environment under threat

1.	(a)	(i)	run off/leaching of (fertiliser / pesticides)	1
		(ii)	Heavy metal pollution or named copper/Cu, lead/ Pb, zinc/Zn.	1
	(b)		Most/highest nitrate/nitrogen OR phosphate (1) eutrophication / Fish suffocate (1)	2
	(c)	(i)	High levels of heavy metal pollution	1
		(ii)	Heavy metal/lead cause poisoning (1) build up to a toxic level / bioaccumulation in birds (1)	2