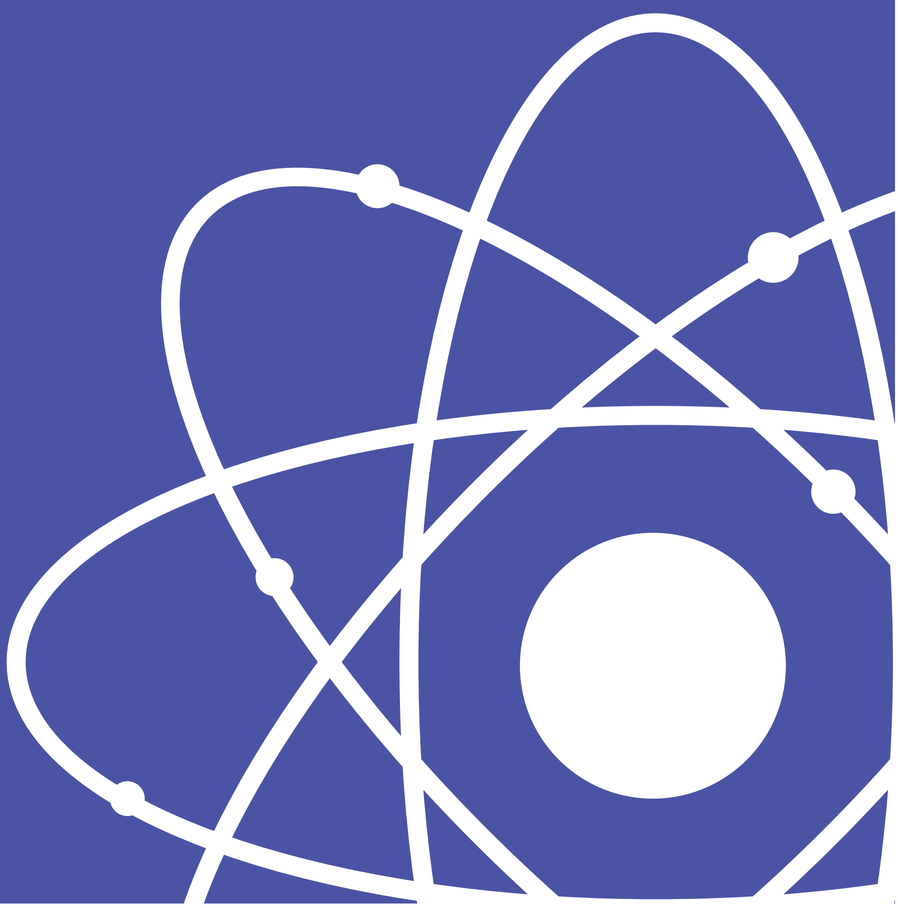
Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)



Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

CELLS AND ORGANISATION

Plant and animal cells

All living things are made up of cells. The structures of different types of cells are related to their functions.

Although animal cells and plant cells have a number of common structures, there are important differences between the two types of cells.

The similarities and differences between plant and animal cells are summed up in the table below.

STRUCTURE	ANIMAL OR PLANT CELL	FUNCTION
nucleus	both	• contains chromosomes which carry genetic information • controls the activities of the cell.
cell membrane	both	• controls the entry and exit of substances
cytoplasm	both	• site of most cell reactions
mitochondrion	both	• site of aerobic respiration
cell wall	plants only	• contains cellulose • structural support for plant cells.
chloroplast	plants only	• site of photosynthesis
vacuole	plants only	• contains a watery sugar solution (sap) • a swollen vacuole pushes the rest of the cell contents against the cell wall, making the cell firm.

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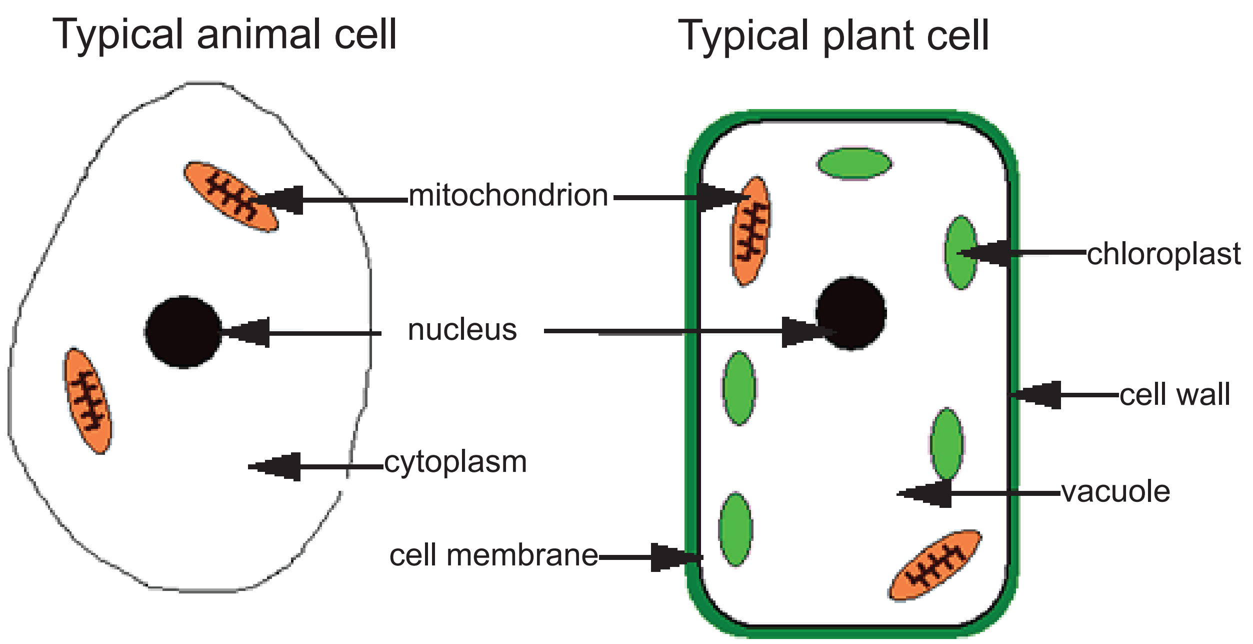
The cell and respiration (specification 1.1.1)

CHECKLIST

- Know the differences between animal and plant cells
- Identify the function of each cell structure.

N.B. You are not required to label a mitochondrion or describe its function at this level. It is included as a link to the section on respiration in this unit (p.16).

Diagram showing key structures in an animal and plant cell



CHECKLIST

Know how to label a diagram of a generalised plant and animal cell.

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The cell and respiration (specification 1.1.1)

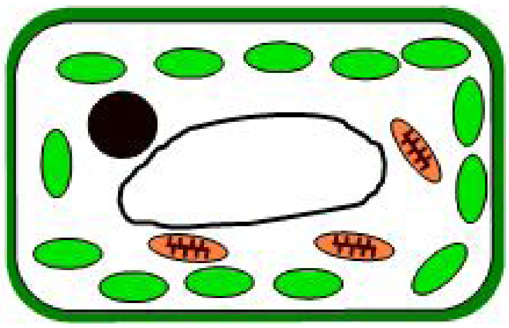
Levels of organisation

Some organisms are made of one cell. These are said to be unicellular. Larger organisms are made of many cells. These are said to be multicellular. The cells in multicellular organisms are not all exactly the same but are specialised for particular functions.

Specialised cells are more efficient at performing specific functions than non-specialised cells.

Examples of specialised cells

Palisade mesophyll cells (from a leaf)



The palisade mesophyll cell is packed with chloroplasts. These cells are regular shaped and form a continuous layer.

This allows the efficient absorption of energy from the Sun.

Red blood cells

Red blood cells
Kiyoshi Takahase Segundo / Alamy Stock Photo

A red blood cell contains haemoglobin which carries oxygen.

There is no nucleus.

The biconcave shape increases the surface area which is important for the efficient absorption of oxygen.

Similar cells that do similar jobs are gathered together into **tissues**.

Examples of tissues include:

- muscle and nerves in animals
- root hair tissue in plants.

Organs are made up of many different tissues working together to perform a function.

Examples of organs include:

- stomach, heart and lung in animals
- root and leaf in plants.

Energy and Life (Unit 1.1)

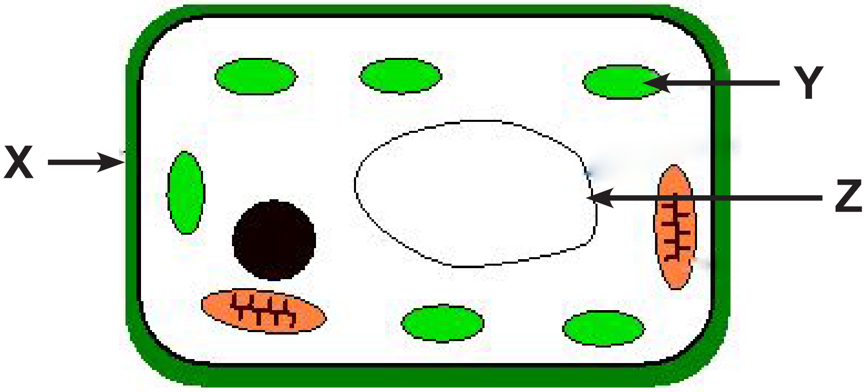
The cell and respiration (specification 1.1.1)

TEST YOURSELF

1. Select **two** features that are common to **both** plant and animal cells.

   A nucleus and cell wall
   B cytoplasm and chloroplast
   C nucleus and cytoplasm

You need to look at the following diagram below for questions 2, 3 and 4.



2. Structure **X** should be labelled:

   A cell membrane
   B cell wall
   C cytoplasm

3. Structure **Y** is a:

   A nucleus
   B chloroplast
   C cytoplasm

4. Structure **Z** is a:

A nucleus
B chloroplast
C vacuole

5. Which statement **best** describes organs?

A Similar cells that do similar jobs are gathered together into organs.
B Organs are made up of many different cells
C Organs are made up of many different tissues working together to perform a function

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

TRANSPORT IN CELLS

The cell membrane controls the entry of substances into the cell and exit of substances out of the cell.

Substances can pass across a cell membrane by **three** different processes:

- diffusion
- osmosis (*this is a special type of diffusion*)
- active transport

Diffusion

Dissolved or gaseous substances can pass through the cell membrane to get into or out of a cell by diffusion.

Diffusion occurs when particles spread. They move from a region where they are in high concentration to a region where they are in low concentration. Diffusion happens when the particles are **free to move**.

Diffusion involves the movement of a substance **down** a **concentration gradient.**

Or, to put another way:

Diffusion involves the movement of a substance **from** an area of **high concentration to** an area of **low concentration.**

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

It is important to remember that diffusion can only occur as long as there is a concentration gradient, i.e. while there is a difference in concentration.

Diffusion is an example of a **passive process.** Energy is **not** required to make diffusion occur.

An example of diffusion

- Oxygen and carbon dioxide, dissolved in water, are exchanged by diffusion in the lungs.
- Oxygen moves down a concentration gradient from the air in the alveoli to the blood.
- Carbon dioxide moves down a concentration gradient from the blood to the air in the alveoli.

Osmosis

Osmosis is a special type of diffusion.

It involves the **diffusion of water molecules**, from a region of higher water concentration to a region of lower water concentration, through a partially permeable membrane.

The cell membrane is an example of a selectively permeable membrane. A **selectively permeable membrane** only lets some substances pass through.

A dilute solution contains a high concentration of water molecules, while a concentrated solution contains a low concentration of water molecules. Since this is a special case of diffusion, osmosis is also an example of a passive process. It does **not** require energy.

Visking tubing

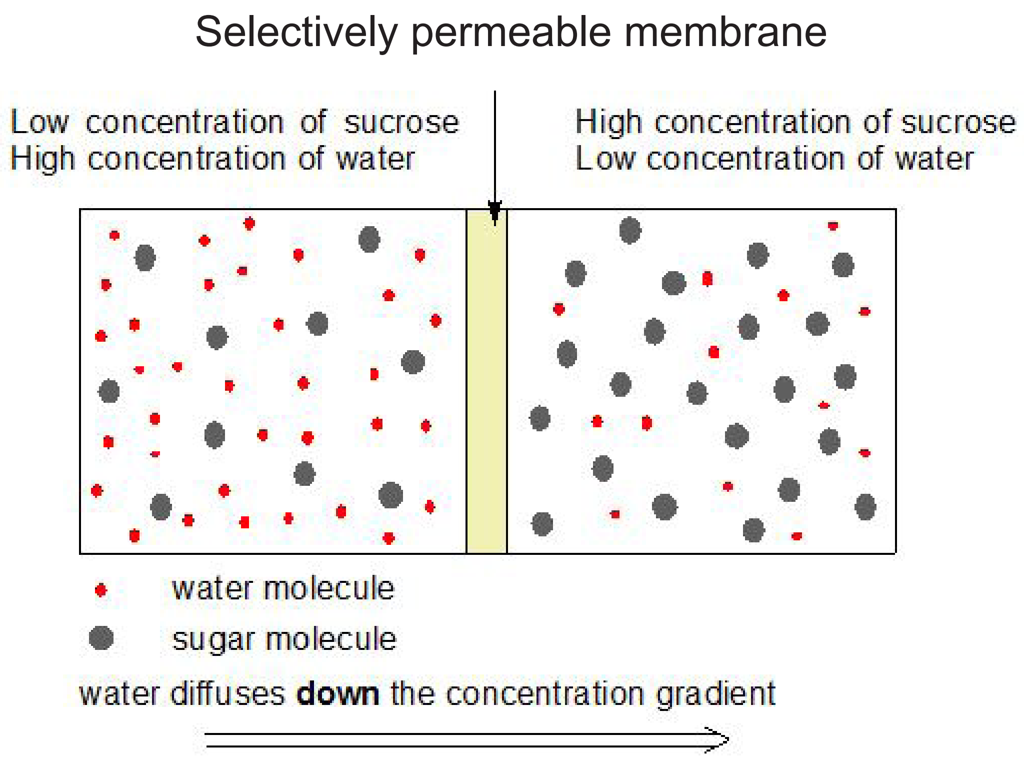
Visking tubing is an artificial selectively permeable membrane which can be used to model living material.

Visking Tubing

Trevor Clifford Photography / Science Photo Library

Visking tubing has **tiny pores** in it which **allow small molecules** (like water and glucose) through but **larger molecules** (like sucrose and starch) are too large to fit through.

Diagram showing direction of diffusion across a selectively permeable membrane

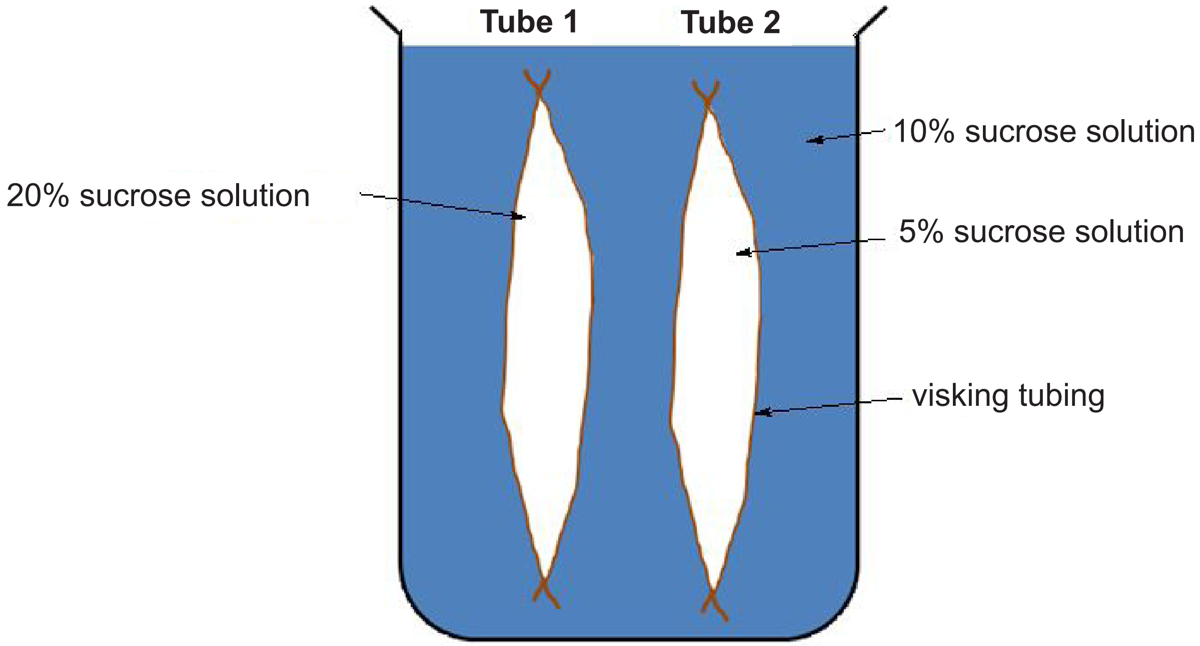


In the diagram above the:

- small water molecules can pass through the small pores in the membrane
- sucrose molecules are too large to pass through the pores in the membrane.

The water molecules can therefore diffuse across the membrane from high concentration to low concentration. The concentration of the water will eventually become the same on both sides of the membrane.

Experiment demonstrating osmosis



Tube 1

- The sucrose concentration is higher than the sucrose solution in the beaker.
- Therefore the water concentration is lower in the tube than in the beaker.
- Water diffuses across the membrane and into the tube. The tube gets bigger.

Tube 2

- The sucrose concentration is lower than the solution in the beaker.
- Therefore the water concentration is higher in the tube than solution in the beaker.
- Water diffuses across the membrane and out of the tube. The tube gets smaller.

Active transport

Foundation tier: You do NOT need to know about active transport.

Sometimes it is necessary for substances to be 'pumped' from a region where they are low in concentration to a region where they are high in concentration. This is in the opposite direction to diffusion. It is known as active transport.

Active transport is the process by which dissolved molecules move across a cell membrane from a lower to a higher concentration.

In active transport, particles move **against the concentration gradient** - and therefore require an input of energy from the cell.

Higher tier: No details are required of the process of ATP synthesis or how it is used to form energy.

The energy for active transport comes from respiration. The cell transfers energy in the form of a molecule called adenosine tri phosphate (ATP).

If respiration in a cell is stopped then active transport can no longer occur.

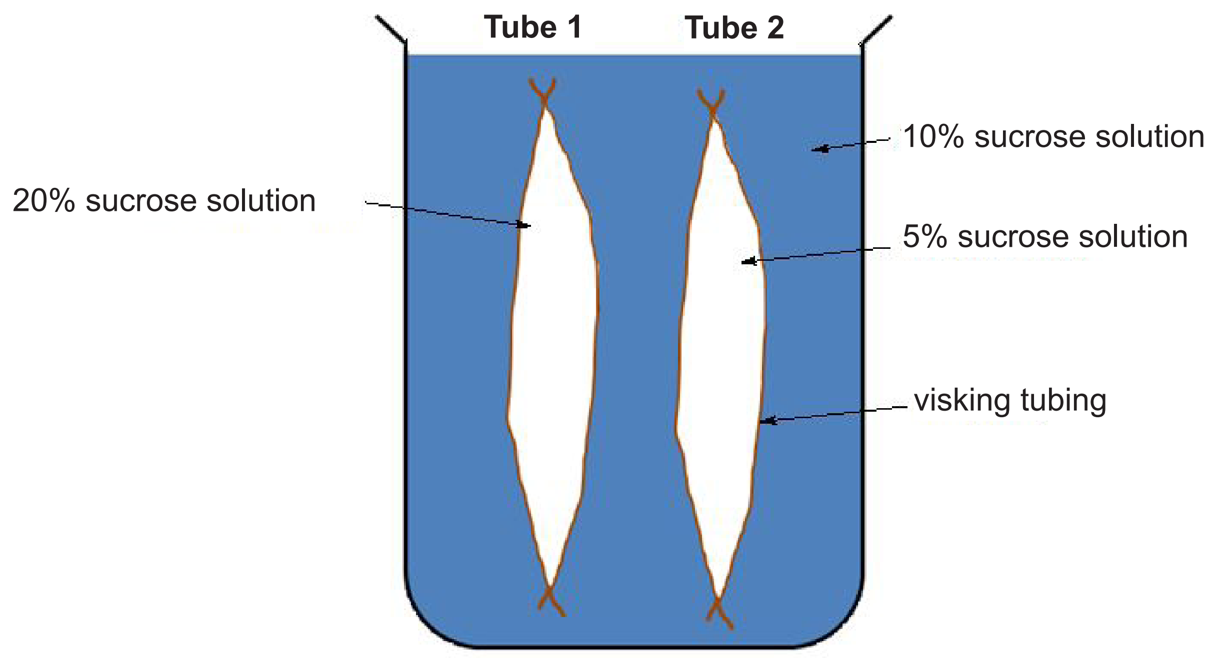
TEST YOURSELF

Complete the following by circling the correct word in brackets:

1. Diffusion involves the movement of a substance **(down / against)** a concentration gradient i.e. diffusion involves the movement of a substance from a region of **(low / high)** concentration to a region of **(low / high)** concentration.

   Osmosis is a special case of **(diffusion / active transport / infusion)** which involves the transport of **(water / starch / energy)** across a selectively permeable membrane from a region of high water concentration to lower water concentration.

2. Look at the diagram below. Select the statement that describes what happens to the tubes.



A Tube 1 and Tube 2 both get larger
B Tube 1 and Tube 2 both get smaller
C Tube 1 gets smaller and Tube 2 gets larger
D Tube 1 gets larger and Tube 2 gets smaller

TEST YOURSELF

3. Which statement is true?

- **A** All molecules can pass through a selectively permeable membrane
- **B** Only small molecules can pass through a selectively permeable membrane
- **C** Only large molecules can pass through a selectively permeable membrane

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

RESPIRATION

All living things need energy to carry out cell processes and so enable organs and systems to work. Respiration occurs in all living things to release this energy.

There are two forms of respiration:

- aerobic respiration
- anaerobic respiration

Both forms of respiration involve a series of enzyme-controlled reactions that obtain energy from glucose.

Be careful: Do not confuse breathing with respiration. Breathing is **NOT** respiration. Breathing is simply a process that gets oxygen into the body and only occurs in some animals.

Aerobic respiration

Aerobic respiration occurs when oxygen is available.

The overall aerobic respiration process can be summarised by the word equation:

glucose + oxygen → carbon dioxide + water (+ energy)

Aerobic respiration:

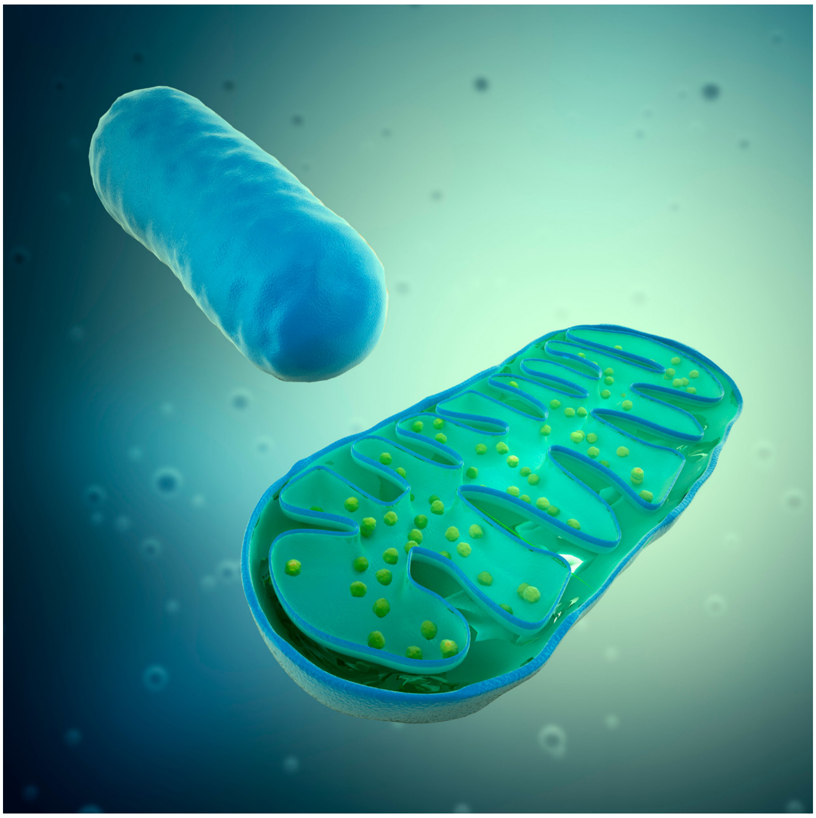
- involves a complex series of reactions which are controlled by enzymes. The word equation above is only a summary of all these processes;
- occurs in animal and plant cells.

Aerobic respiration takes place in tiny structures in the cell called **mitochondria.**

Muscle cells need a lot of energy and therefore are packed with mitochondria.

Some of the energy from respiration is lost as heat.

For this reason, your muscles warm up when you do strenuous exercise and this can raise your core temperature.



Mitochondria

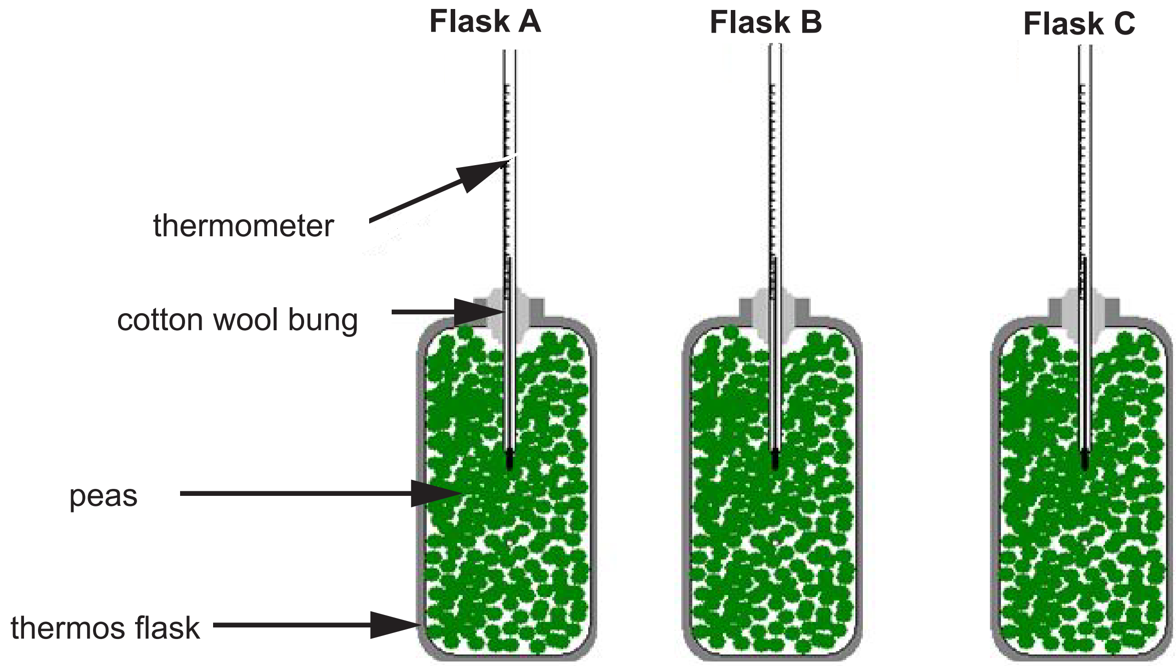
Science Photo Library / Alamy Stock Photo

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

Investigating the energy released as heat during aerobic respiration

Pea seeds were packed into three thermos flasks. The thermos flasks prevented heat loss. A cotton wool plug was used to hold a thermometer in place. The cotton wool plug allowed carbon dioxide to escape. The temperatures were measured at the beginning and the end of the week.



Results after one week

Flask	Contents of flask	Flask temperature (°C)		Temperature change (°C)
		Start of week	End of week	
A	pea seeds	19	32	13
B	boiled pea seeds	19	26	7
C	boiled pea seeds in disinfectant	19	19	0
Flask A	Temperature has increased because heat is released during respiration of the living pea cells.			
Flask B	The peas were killed by boiling. There is a small temperature increase because microbes such as bacteria are present. These release heat during respiration in their cells.			
Flask C	A control flask. The peas are dead. The disinfectant has also killed any bacteria. No respiration is occurring.			

In the absence of oxygen, cells may obtain energy using **anaerobic respiration.**

Anaerobic respiration involves the **in**complete breakdown of glucose. This is a much less efficient form of obtaining energy than aerobic respiration.

Only about 5% of the energy released during aerobic respiration, per molecule of glucose is obtained. The waste product is lactic acid rather than carbon dioxide and water.

The word equation for **anaerobic respiration** is:

glucose → lactic acid (+ energy)

Anaerobic respiration occurs in human muscles as a result of vigorous exercise, when the demand for oxygen is greater than can be supplied from the lungs.

Lactic acid, which is toxic, builds up in the muscles causing pain and tiredness.

The existence of an oxygen debt explains why we continue to breathe deeply and quickly for a while after exercise.

Female hurdler

Juice Images / Alamy Stock Photo

Oxygen debt

The extra oxygen required to oxidise the lactic acid formed during anaerobic respiration to carbon dioxide and water is called the **oxygen debt.**

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

TEST YOURSELF

1. The word equation for aerobic respiration is:

A glucose → lactic acid (+ energy)
B glucose + oxygen (+ energy) → carbon dioxide + water
C glucose + oxygen → carbon dioxide + water (+ energy)

2. Select the statement that is true:

A More energy is released in aerobic respiration than anaerobic respiration for same amount of glucose
B More energy is released in anaerobic respiration than aerobic respiration for same amount of glucose
C About the same amount of energy is released in anaerobic respiration as aerobic respiration

3. Aerobic respiration occurs in:

A plant cells but not animal cells
B animal cells but not plant cells
C both plant and animal cells

4. Lactic acid is formed during:

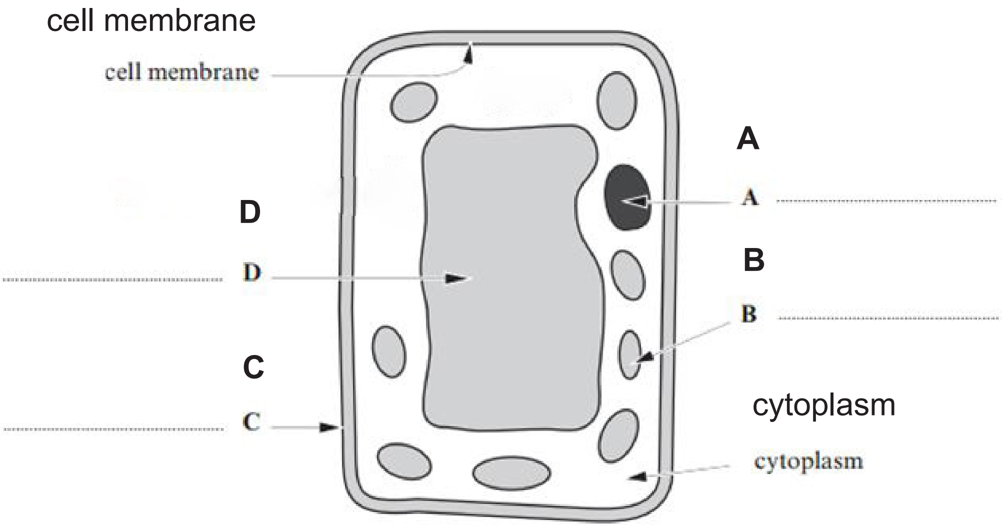
A anaerobic respiration
B aerobic respiration
C both anaerobic and aerobic respiration

Energy and Life (Unit 1.1)

The cell and respiration (specification 1.1.1)

PRACTICE QUESTIONS

1. Plant biologists have examined some cells under the microscope
Label the parts **A, B, C** and **D** on the diagram below.



2. Athletes running the marathon often experience 'hitting the wall', where almost all of the athlete's energy stores are depleted, at around the 20-mile (32 km) point. This can be delayed by changing to a diet which is carbohydrate loaded a few days before the race.

(a) Name and describe the process in body cells that releases the energy used by the athletes.

[3]

....

....

(b) Explain how insufficient oxygen supply to the cells during exercise will affect the athlete's body.

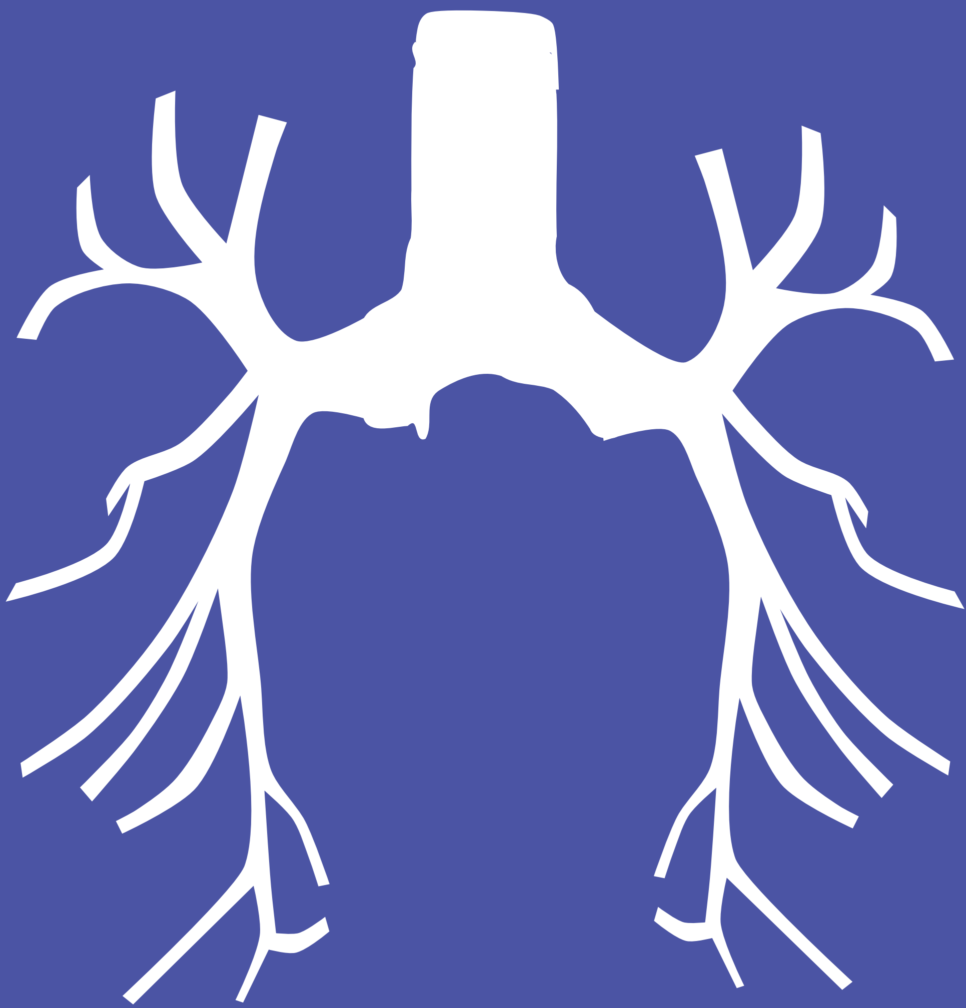
[3]

....

....

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)



Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

THE RESPIRATORY SYSTEM

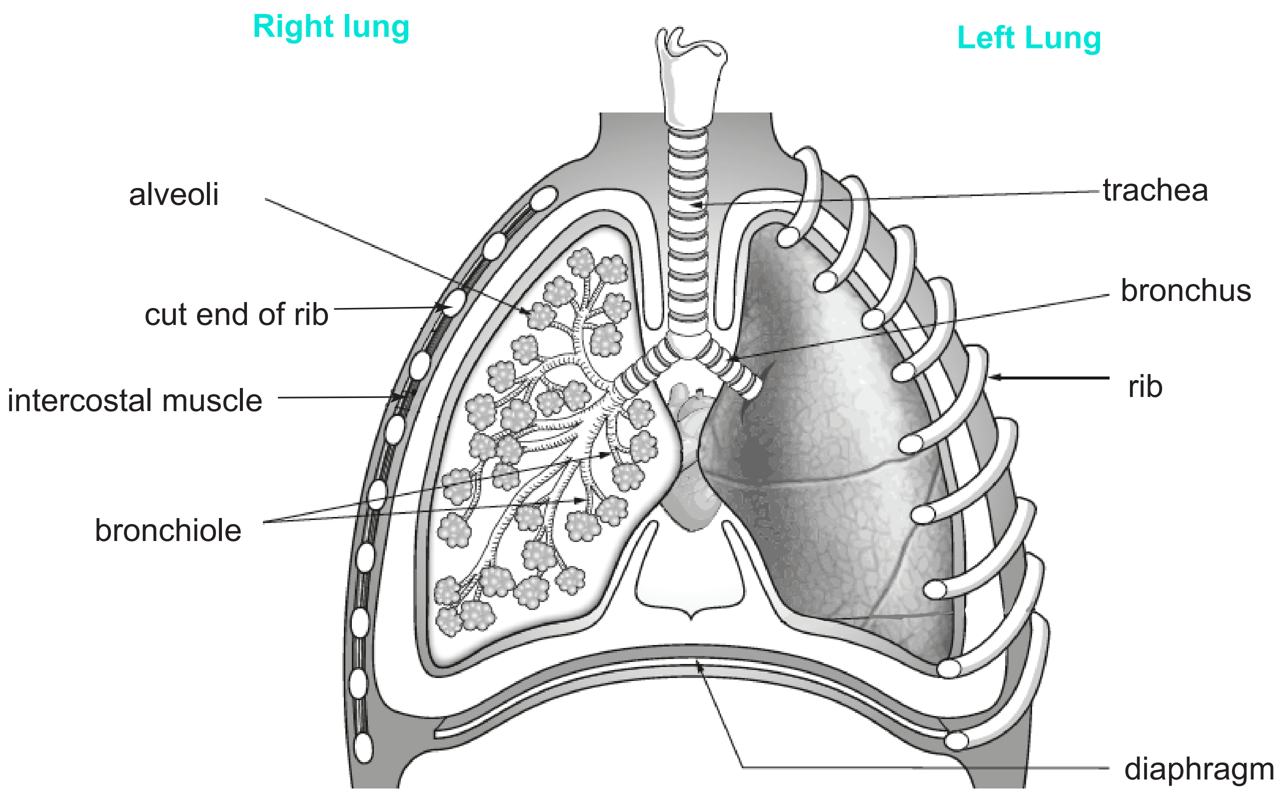
We have already seen that cells need oxygen for aerobic respiration. Very simple organisms rely on diffusion to provide the oxygen they need but large organisms require a complex respiratory system.

The **purpose of the respiratory system** is to provide sufficient oxygen to maintain a high level of aerobic respiration and to remove an equivalent volume of waste carbon dioxide.

Checklist:
Know how to label a diagram of the human respiratory system.

The human respiratory system

The organs of gas exchange in humans are the lungs.
The lungs are found inside the thorax (chest).



Inside the thorax

Significantly modified diagram based upon http://pastpapers.download.wjec.co.uk/s12-4471-01.pdf q5

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

The breathing mechanism: How air is breathed in and breathed out

Breathing is caused by movements of the rib cage and the diaphragm.

The steps are:

Breathing in (inspiration)

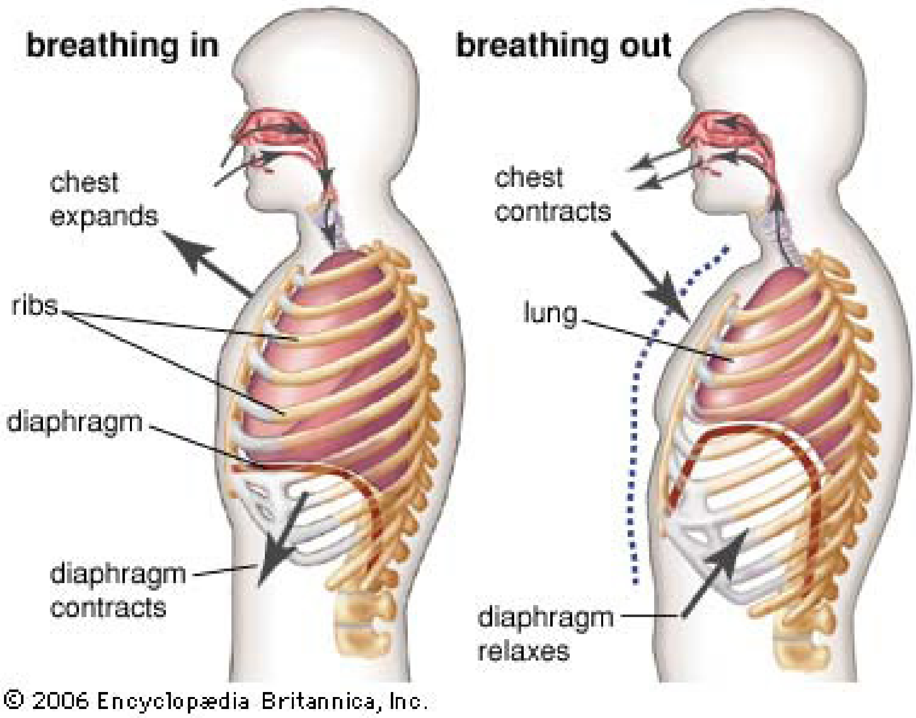
1. The intercostal muscles contract and move the ribs upwards and outwards;
2. The diaphragm contracts and flattens.

Both these actions **increase the volume** of the cavity containing the lungs so **decreasing the pressure.** This means air is drawn into the lungs.

Breathing out (expiration)

1. The intercostal muscles relax and the ribs move downwards and inwards;
2. The diaphragm relaxes and domes upwards.

These actions **decrease the volume** of the cavity containing the lungs and so **increasing the pressure.** This means air is forced out of the lungs.



Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

The role of alveoli in gas exchange

Gas exchange takes place in the alveoli. Alveoli are air sacs at the end of the bronchioles. In the alveoli, carbon dioxide is expelled and oxygen is absorbed.

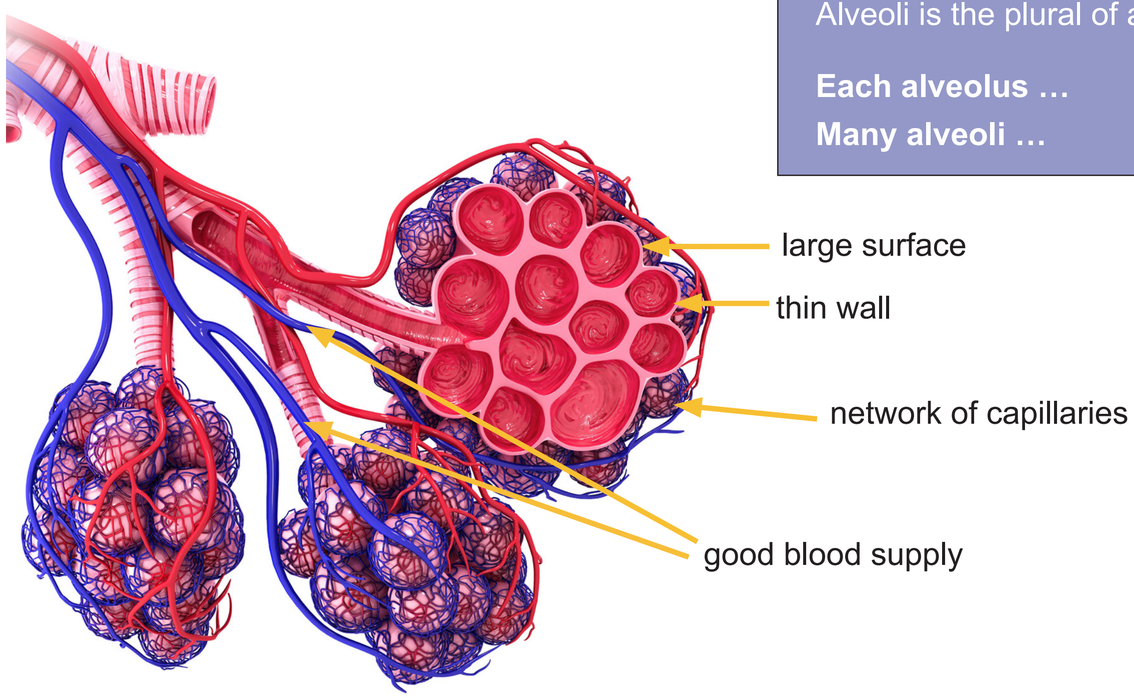
There are a very large number of alveoli in the lungs.

Alveoli are adapted for gas exchange in the following ways:

- They have a **large surface area.** (*The total area of alveoli, if spread out, is about the same as a tennis court*).
- Alveoli have a **moist lining** which allows oxygen to dissolve. This is necessary for diffusion to occur.
- Alveoli have **thin walls**. This allows the gases to diffuse through quickly and easily.
- Alveoli have a good blood supply. Blood **capillaries** at the surface of each alveolus carry oxygen to the rest of the body and also bring carbon dioxide to be expelled.

Don't get confused by your alveoli and alveolus!
Alveoli is the plural of alveolus.

Each alveolus …
Many alveoli …



Alveoli

Science Photo Library / Alamy Stock Photo

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

TEST YOURSELF

---

1. Complete the sentences, by selecting the correct words in the brackets, to describe the steps in **breathing in:**

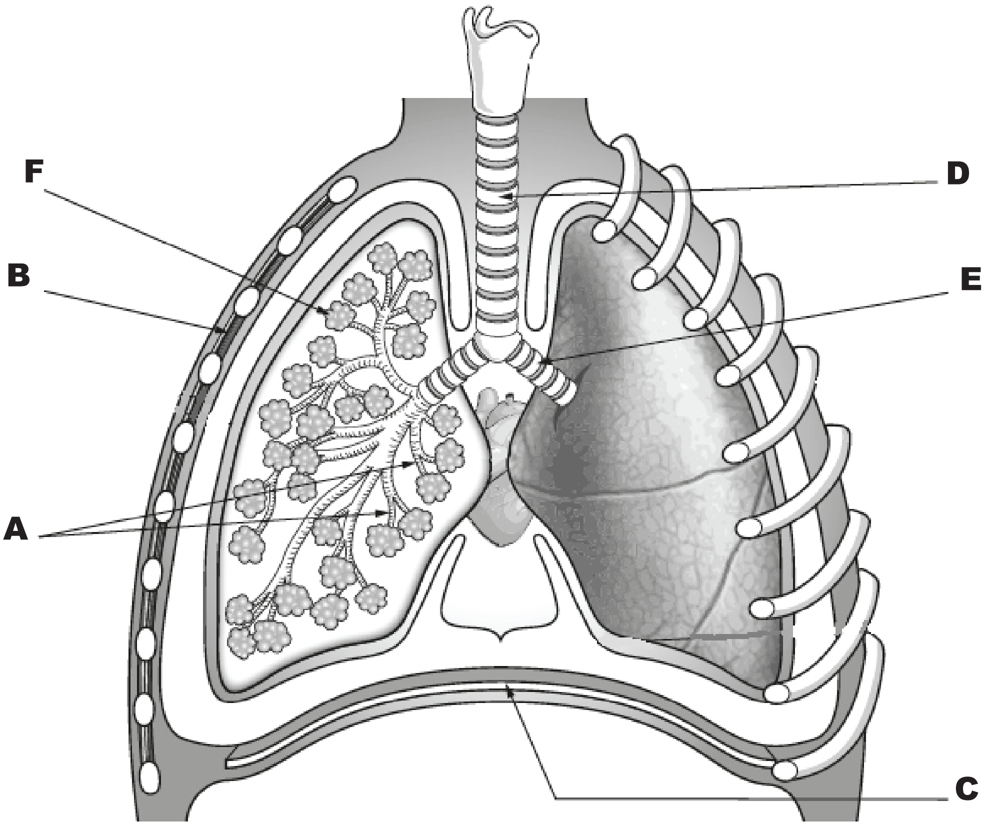
- **a)** The intercostal muscles (**contract / relax**) and move the ribs upwards and outwards
- **b)** The diaphragm (**relaxes / contracts**) and (**flattens / domes upwards**)

2. State where gas exchange takes place in the lungs.

- **A** alveoli
- **B** bronchioles
- **C** trachea

3. Match the following labels to the letters on the diagram.

trachea	intercostal muscle	alveoli	diaphragm	bronchus	bronchioles



Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

DIGESTION

Food provides the energy the body needs. In order to do this it needs to travel to all parts of the body in the blood stream. For this to happen, it is necessary that the food is:

- broken down into small molecules that can get through the wall of the gut into the blood stream;
- soluble in water so that it can dissolve in the blood.

> **Digestion** is the process whereby large insoluble molecules are broken down into smaller soluble molecules so that they can be absorbed for use by body cells.

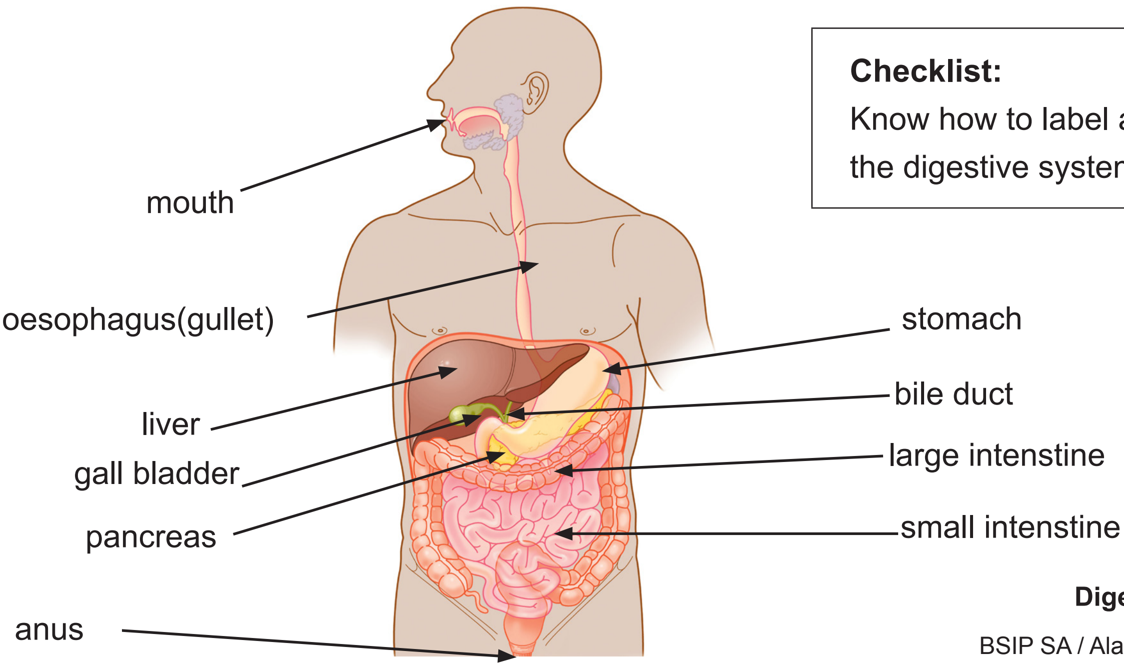
The digestive system

The digestive system is adapted to break down and absorb food. There are two important aspects of digestion:

- mechanical digestion which breaks the food down into smaller pieces
- chemical digestion which breaks these pieces into smaller molecules.

The diagram below shows the main features of the digestive system:

> **Checklist:**
> Know how to label a diagram of the digestive system.



Digestive system

BSIP SA / Alamy Stock Photo

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

The function of organs in digestion

The function of some key organs in digestion is shown in the table below.

ORGAN	FUNCTION
mouth	• breaks up food by chewing • carbohydrase (amylase) in saliva starts starch digestion
stomach	• produces hydrochloric acid and protease to start protein digestion
liver	• secretes bile
gall bladder	• stores bile
pancreas	• produces lipase, protease and carbohydrase and secretes these enzymes into the small intestine
small intestine	• continued digestion of - carbohydrates to glucose - proteins to amino acids - fats to fatty acids and glycerol • absorption of digested molecules
large intestine	• absorption of water

Bile

Bile is a liquid produced by the liver and stored in the gall bladder. It is secreted down the bile duct into the small intestine.

Bile does not contain enzymes. Its function is to **emulsify fats**, breaking them into small droplets. This **increases** the surface area of the fat for action of the enzyme lipase.

Bile also increases the pH in the small intestine to the optimum pH for enzyme activity, and neutralise the acid from the stomach.

Energy and Life (Unit 1.1)

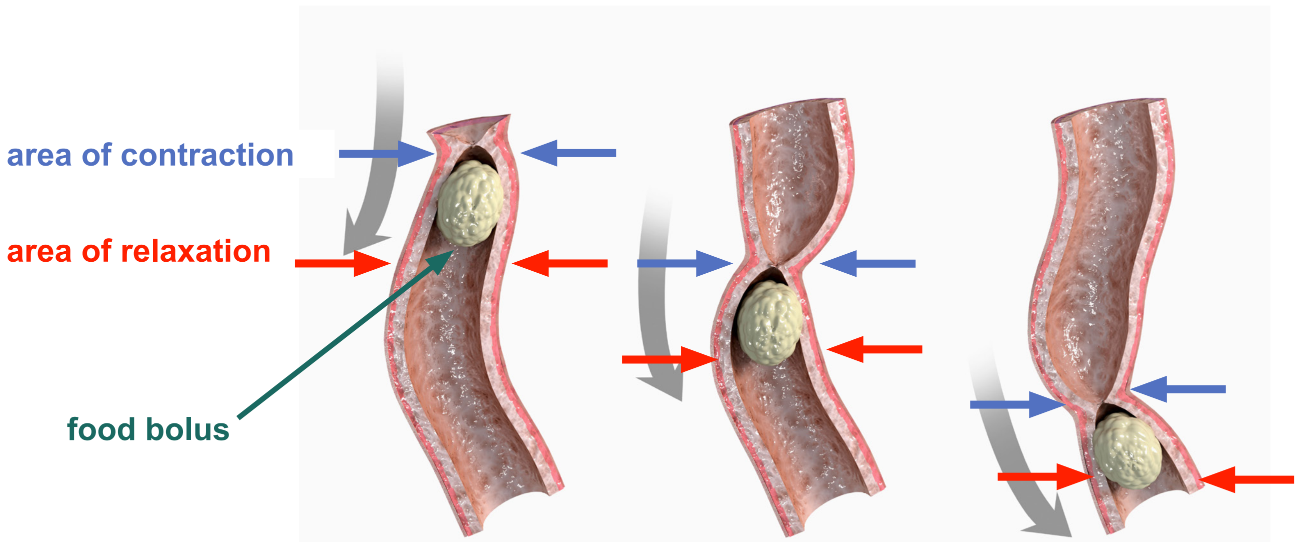
Obtaining the materials for respiration (specification 1.1.2)

Movement of food

Food is moved along the digestive tract by a process known as **peristalsis**.

This involves the contractions of gut muscles behind the food and the relaxation of muscles in front of the food.

Their wave-like contractions create a squeezing action, moving down the gut.



Peristalsis

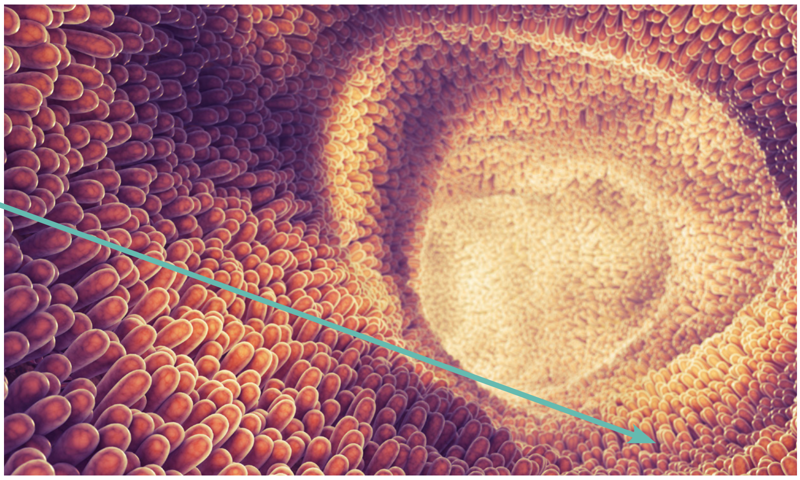
MedicalRF.com / Alamy Stock Photo

Absorption of soluble substances

In the small intestine, small digested food molecules are absorbed into the blood stream by **diffusion.**

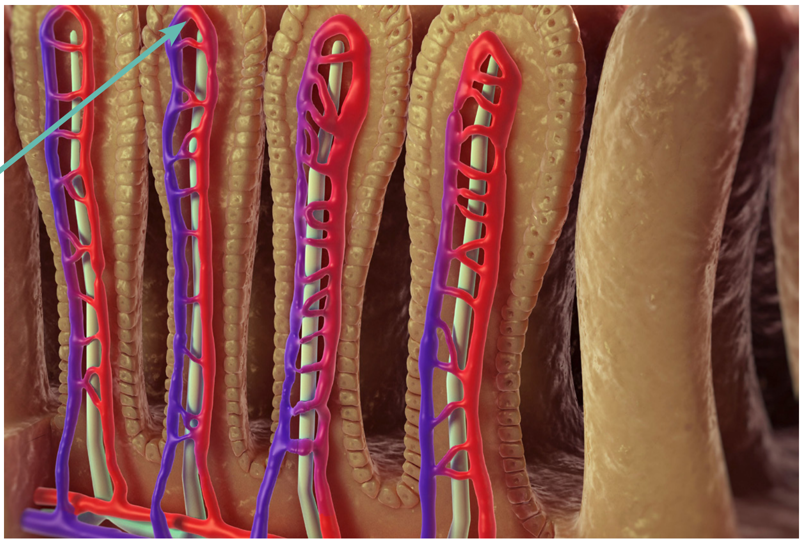
The inside wall of the small intestine is thin and has a large surface area created by **tiny villi** which contain blood capillaries. The blood capillaries carry away the absorbed food molecules which diffuse across the wall of the intestine. The rich blood supply also maintains a steep concentration gradient which means absorption happens quickly and efficiently.

Diagram of small intestine lining and villi



Intestine lining
nobeastsofierce Science / Alamy Stock Photo

Diagram showing blood supply to villi

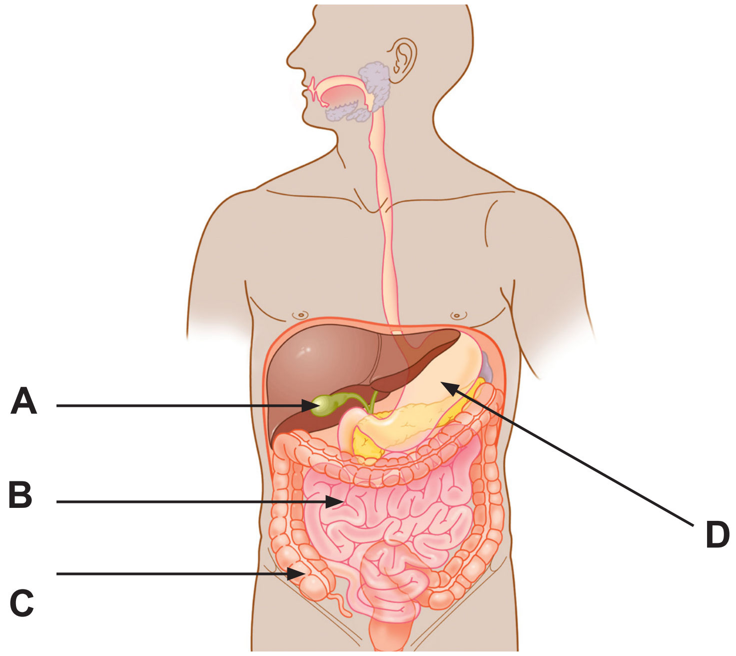


Intestine villi
The Science Picture Company / Alamy Stock Photo

TEST YOURSELF

1. Label **A, B, C** and **D** in the diagram below. Use the following words:

stomach gall bladder small intestine large intestine



Digestive system

BSIP SA / Alamy Stock Photo

2. The function of the gall bladder is to store:

A enzymes **B** acid **C** bile

3. Select the correct words in brackets below.

Food travels along the gut by a process known as (**peripstalsis / peristalsis / prepistalsis**).
This involves the (**contraction / relaxation**) of gut muscles behind the food and the (**contraction / relaxation**) of muscles in front of the food.

4. Food molecules are absorbed into the gut by:

A. osmosis **B.** diffusion **C.** active transport

Enzymes

Enzymes are produced by every living organism and control all the chemical reactions that occur in cells. There are many different enzymes and each one has a specific role.

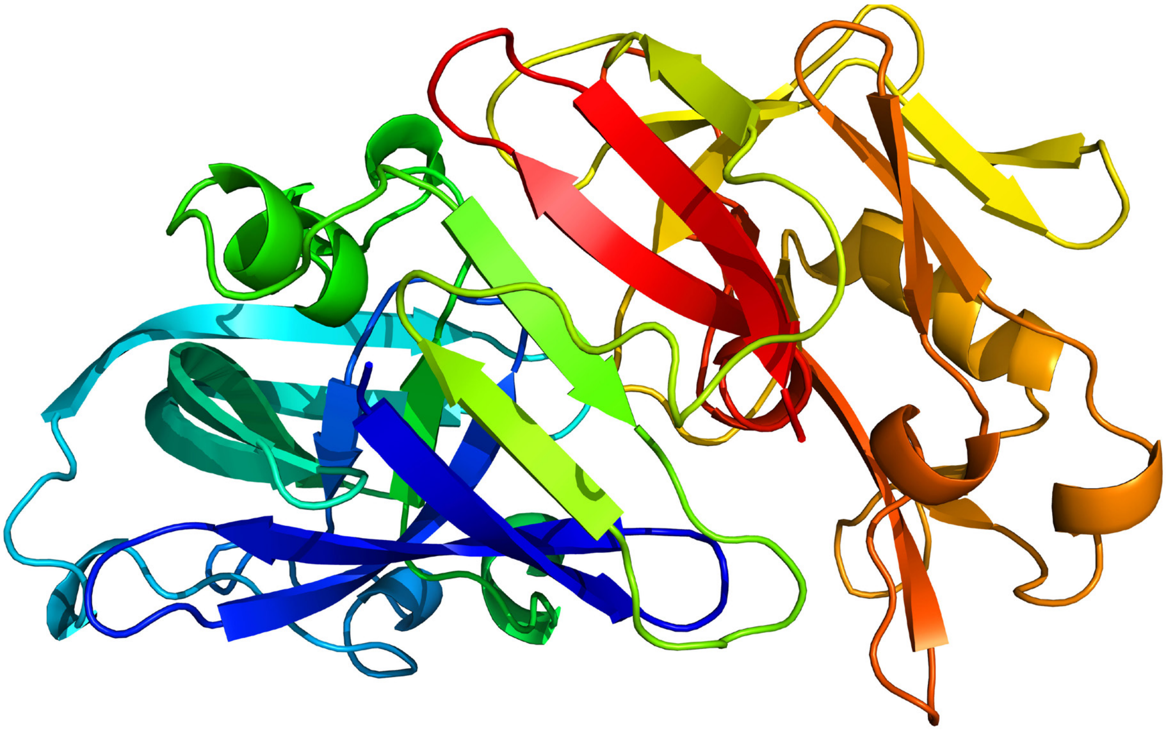
An **enzyme** is a biological catalyst.

They speed up (catalyse) the rate of chemical reactions that occur within the cells.

The structure of enzymes

Enzymes are proteins that are folded into complex shapes.

Proteins are important chemicals found in many forms in living things. **Proteins** are long chain molecules made by linking together smaller molecules called **amino acids.** Apart from enzymes, important proteins include hormones and muscle tissue.



Computer model of a digestive enzyme showing complex 3D structure

ibreakmedia / Alamy Stock Photo

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

How enzymes work

The three-dimensional shape of an enzyme is essential to the ability of the enzyme to catalyse a reaction. Enzymes are folded into complex shapes that allow smaller molecules to fit into them. The part of the enzyme where these molecules fit is called the **active site.**

If the shape of the active site is destroyed, the enzyme will no longer be able to bind with the substrate and the reaction can no longer occur. The enzyme is said to be **denatured.**

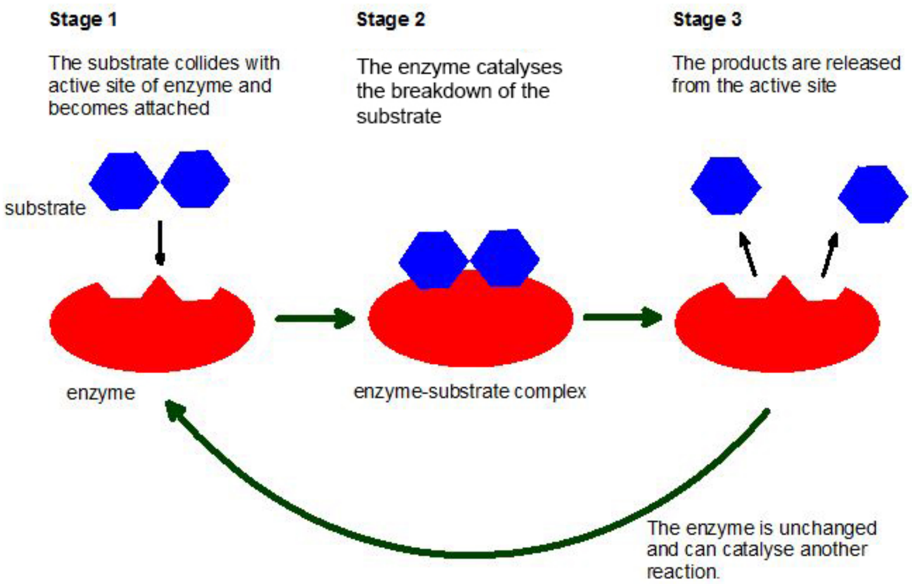
The substrate is the reacting molecule that binds to the active site.

The 'lock and key' model

Foundation tier: You do **NOT** need to know about the lock and key model.

In the lock and key model, the shape of the active site matches the shape of its substrate molecule. This makes enzymes highly specific – each type of enzyme can catalyse only one type of reaction.

The diagram shows how this works. In this example, a large molecule is split into two smaller ones. Other enzymes can join small molecules together to make larger ones.



Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

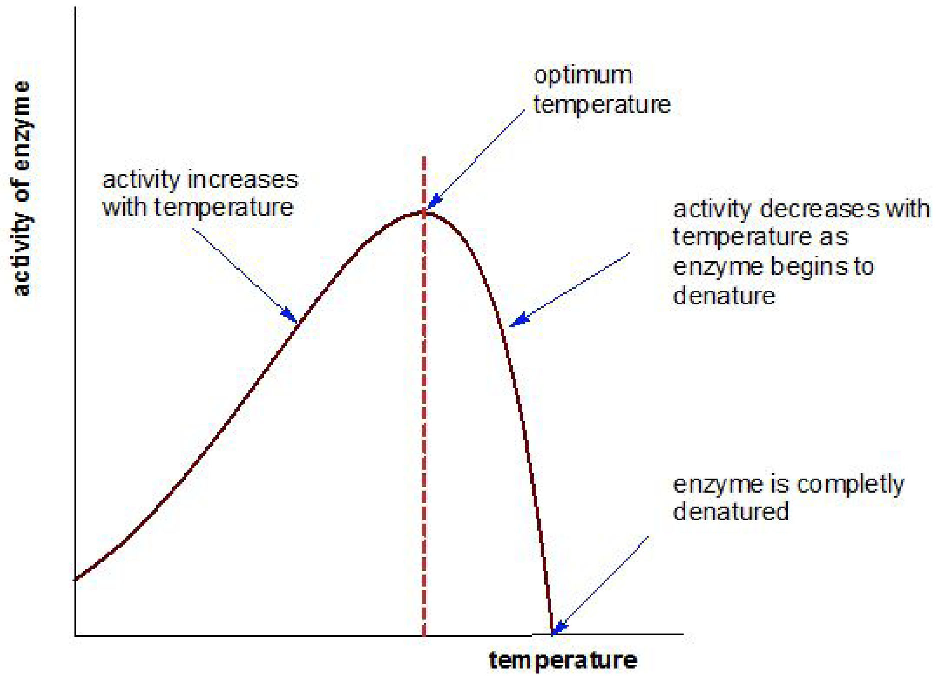
Properties of enzymes

Enzymes are designed to work best at a particular temperature and pH.

The **optimum** temperature or pH is the temperature or pH at which the rate of enzyme action is the greatest.

Temperature and enzyme activity

A graph showing the effect of temperature on the rate of an enzyme-controlled reaction is shown below.



NOTICE

- The enzyme activity gradually increases with temperature until it reaches the optimum temperature. The enzyme and substrate molecules move more rapidly as temperature increases allowing them to lock together.
- As the temperature continues to rise, the rate of reaction falls rapidly because the enzyme is denatured by the heat energy.

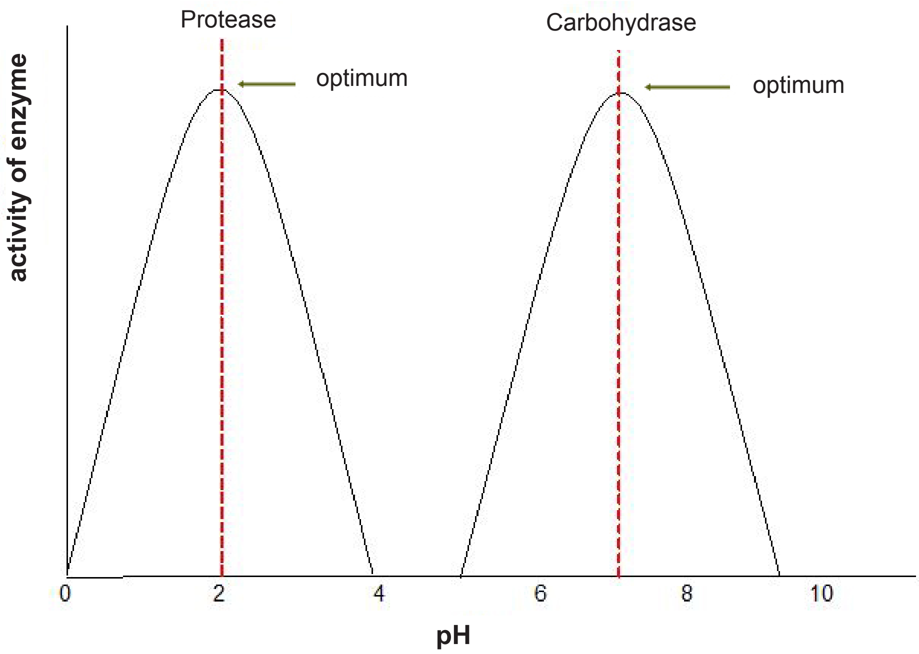
Heat energy denatures the enzyme, i.e. it alters the shape of the protein so that the enzyme is no longer able to function.

pH and enzyme activity

Enzymes are designed to work within a narrow pH range since changes in pH alter the shape of an enzyme. Different enzymes work best at different pH values. The optimum (best) pH for an enzyme to work depends on where the enzyme is found.

The pH of the stomach is about 2, so enzymes that work in the stomach have an optimum pH of about 2. Enzymes that work in the small intestine have an optimum pH of about 7.5 which is the pH in the small intestine.

A graph showing the effect of pH on the rate of reaction of digestive reactions controlled by two different enzymes is shown below.



The two enzymes have different optimum pH values.

Protease is an enzyme that is found in the stomach where the pH is about 2. It therefore has an optimum pH of 2.

Carbohydrase is found in the small intestine where the pH is about 7.5, so this is the optimum pH of this enzyme.

Notice that the graph also shows that enzymes can also be denatured by changing pH, i.e. changing pH changes the shape of the protein so that it is no longer able to function.

TEST YOURSELF

1. Enzymes are:

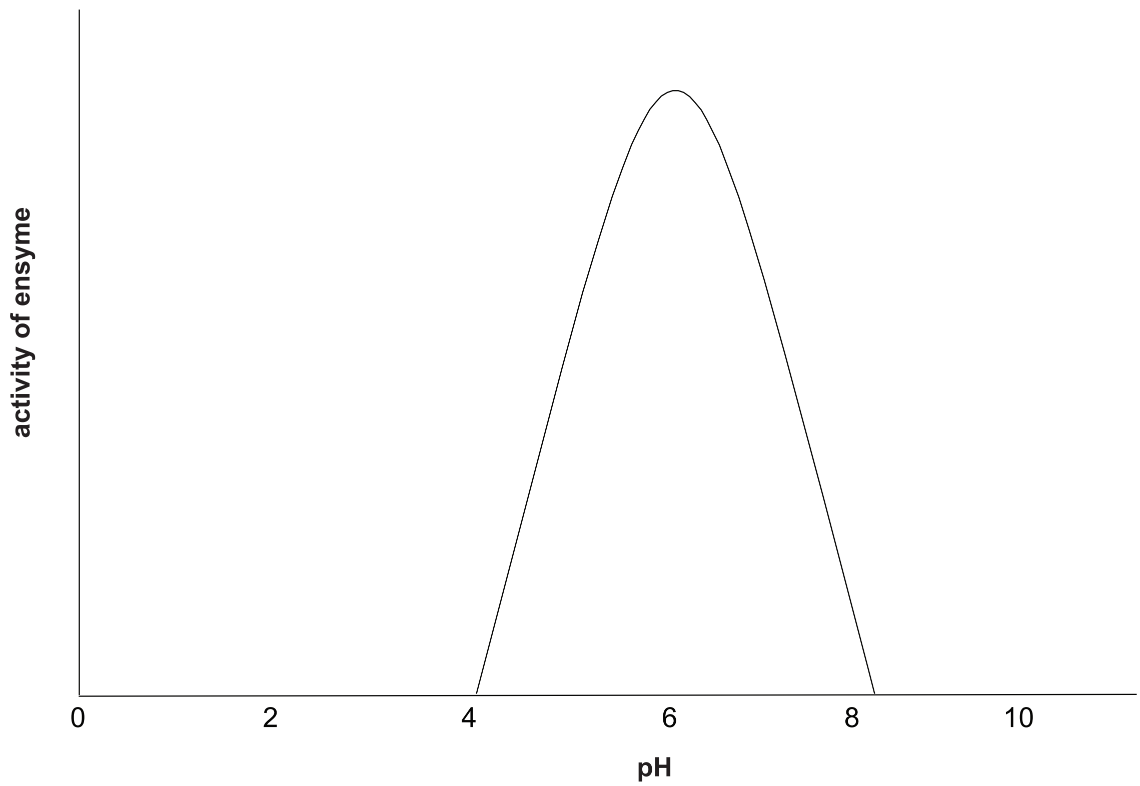
A found in plant and animal cells
B only found in plant cells
C only found in animal cells

2. Enzymes:

A slow chemical reactions down
B increase the rate of chemical reactions
C have no effect on chemical reactions

TEST YOURSELF

You will need to use the graph below showing how the activity of an enzyme changes with pH to answer Q3 and Q4.



3. The optimum pH for the reaction is approximately pH

A 4 **B** 6 **C** 8.2

4. The enzyme is completely denatured at pH

A 4 **B** 6 **C** 8.2

The digestion of starch, fats and proteins

Remember that we have already seen that only simple soluble molecules can be absorbed by the gut. Other more complex compounds need to be digested.

It is the role of enzymes in the digestive system to enable these changes to take place.

Substance	Digested into	Function in the body	Enzyme
starch	glucose	provides energy	carbohydrase (amylase)
fats	fatty acids and glycerol	• provide energy • insulation	lipase
protein	amino acids	• growth • repair	protease

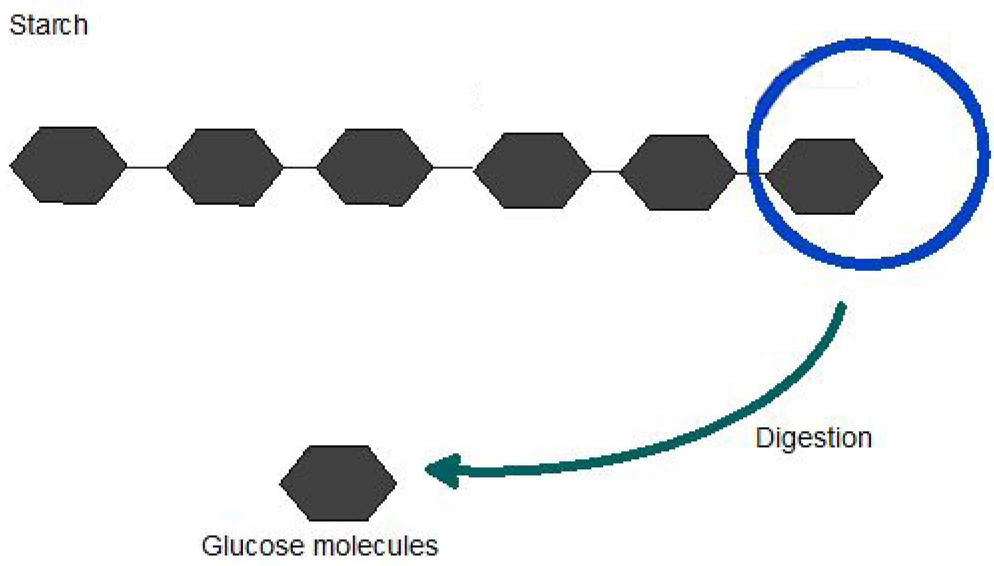
Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

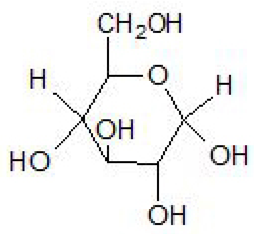
A closer look at what happens to molecules in digestion

Starch to glucose

Starch is made of glucose molecules joined together in a long chain. It is **in**soluble and cannot diffuse through the gut wall. Carbohydrase (amylase) is the enzyme which catalyses the breakdown of starch into smaller soluble glucose molecules in saliva and the small intestine.



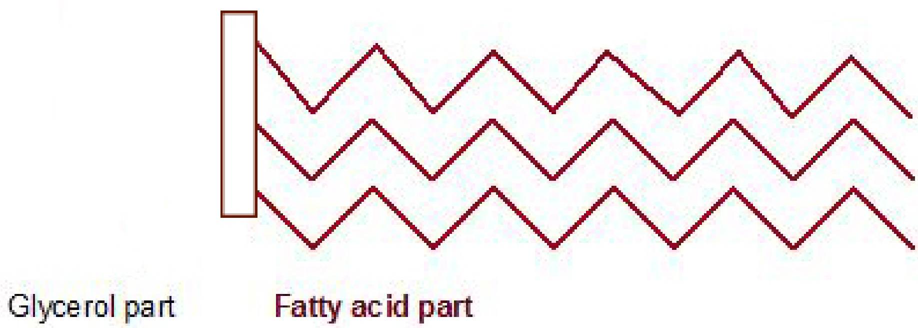
The structure of glucose is $C_6H_{12}O_6$.
It is a ring structure.



You do not need to be able to draw the complex chemical structure of glucose in the exam but you must be able to recognise the relationship between starch and glucose.

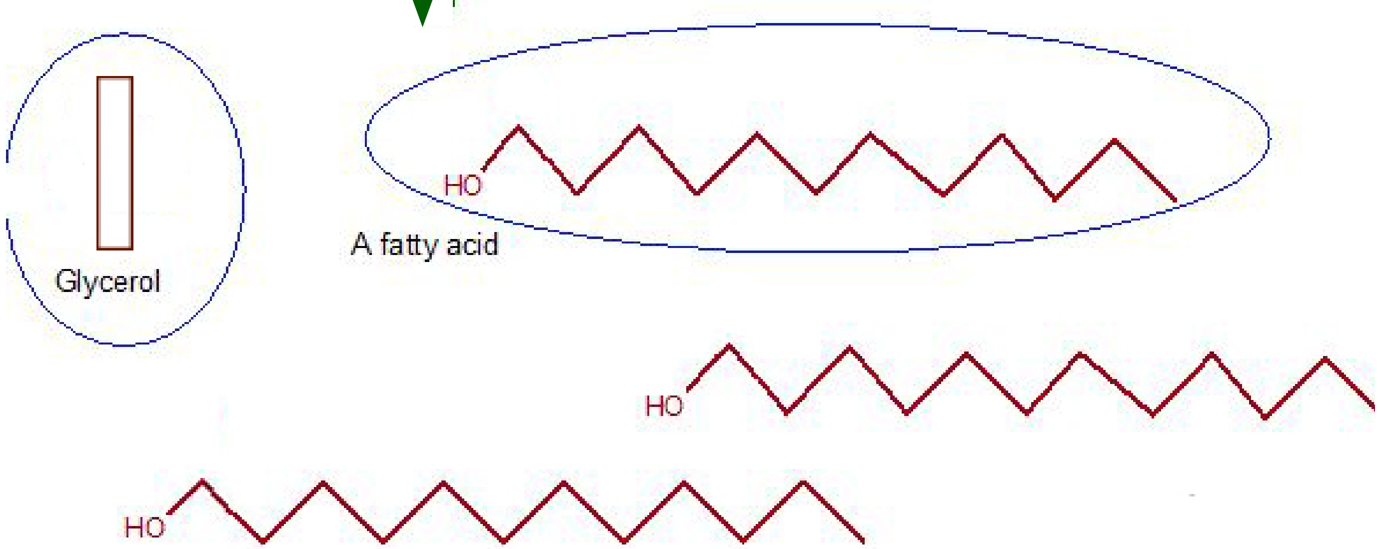
Fats to fatty acids and glycerol

Fats and oils (lipids) are made up of fatty acids and glycerol. Lipase is the enzyme which catalyses the breakdown of fat into glycerol and fatty acids in the small intestine. Both these products can diffuse through the gut wall.



During digestion fats are broken down into small molecules, glycerol and fatty acids.

Make sure you are able to recognise the relationship between fat and fatty acids and glycerol.



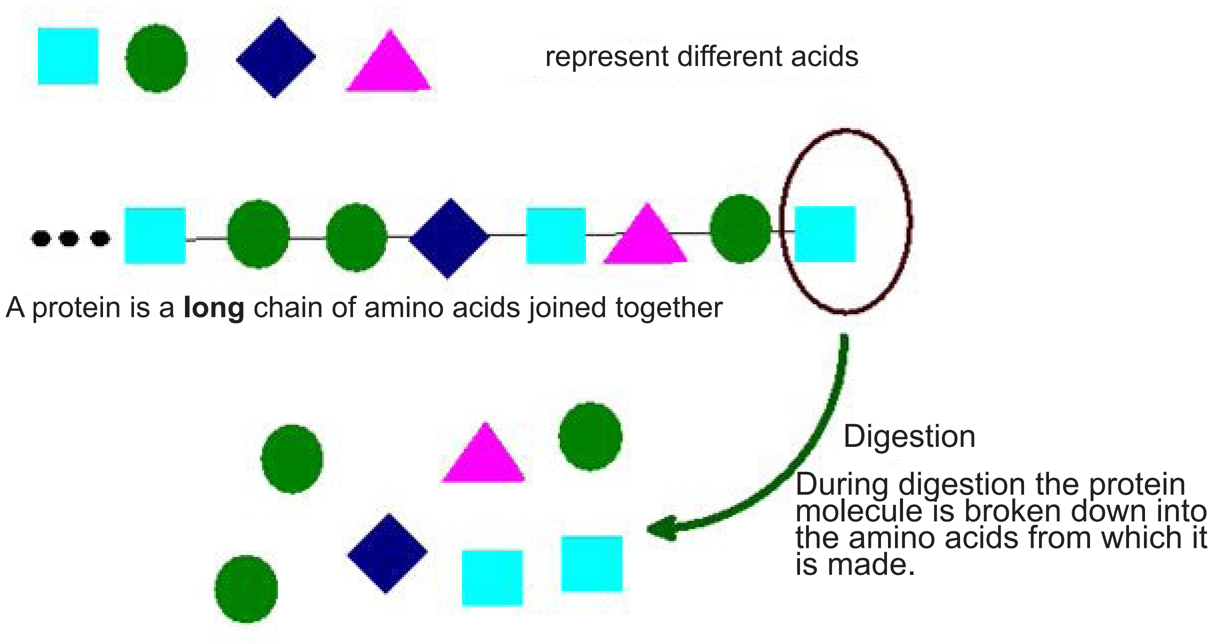
Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

Proteins to amino acids

Proteins are built from smaller molecules called amino acids. Amino acids are able to diffuse through the gut wall.

Protease is the enzyme that catalyses the breakdown of proteins into amino acids. Proteins are digested in the small intestine.



These amino acids can be used to make new proteins.

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

TEST YOURSELF

1. Identify **W, X, Y** and **Z** in the table below by using the following words

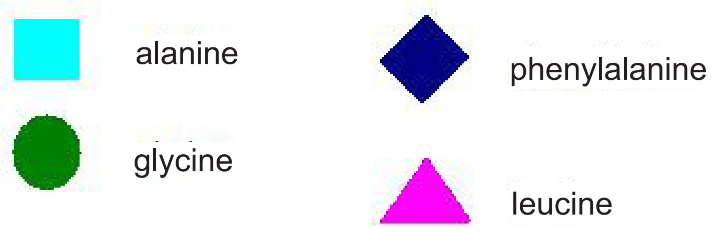
FATS	**LIPASE**	**GLUCOSE**	**PROTEIN**

Substance	Digested into	Function in the body	Enzyme
W	amino acids	growth and repair	protease
starch	**X**	provides energy	carbohydrase
Y	fatty acids and glycerol	provide energy	**Z**

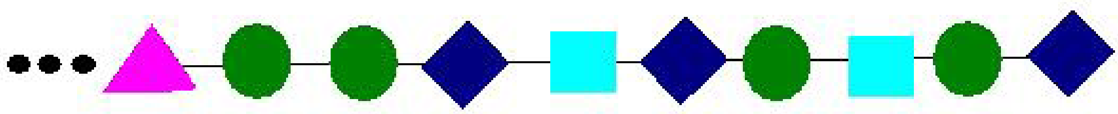
TEST YOURSELF

2. A part of a protein chain is shown below.

Use the key below to work out the number of each amino acid you will obtain by the digestion of this part of the chain.



Part of the protein chain



Amino acid	Number
alanine	
glycine	
phenylalanine	
leucine	

Don't worry about names of amino acids. You are not required to remember them.

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

Food tests

Foods can be tested to see if they contain starch, glucose or protein.

Food	Test	Observation
Starch	Add iodine solution	Turns from brown to blue-black in the presence of starch
Glucose	Add Benedict's solution place in a boiling water bath	Gradually turns from blue to brick red
Proteins	Add biuret reagent	Turns from blue to violet colour in the presence of protein

Starch
Martin Shields / Alamy Stock Photo

Starch can be tested for by dropping iodine onto the test substance.

If it turns blue-black then starch is present.

Test tubes
Martyn F. Chillmaid / Science Photo Library

The test tube on the left contains Benedict's solution.

The tube to the right shows the result of heating Benedict's solution with a solution of glucose.

Solutions containing glucose will turn green, orange or brick red, depending upon how much glucose is present.

Checklist:
Know the colours of each reagent, what it tests for and the colour change produced.

A model gut

Visking tubing can be used to model the gut. Visking tubing is a selectively permeable membrane. It allows small molecules to pass through but not larger molecules.

Limitations of the model

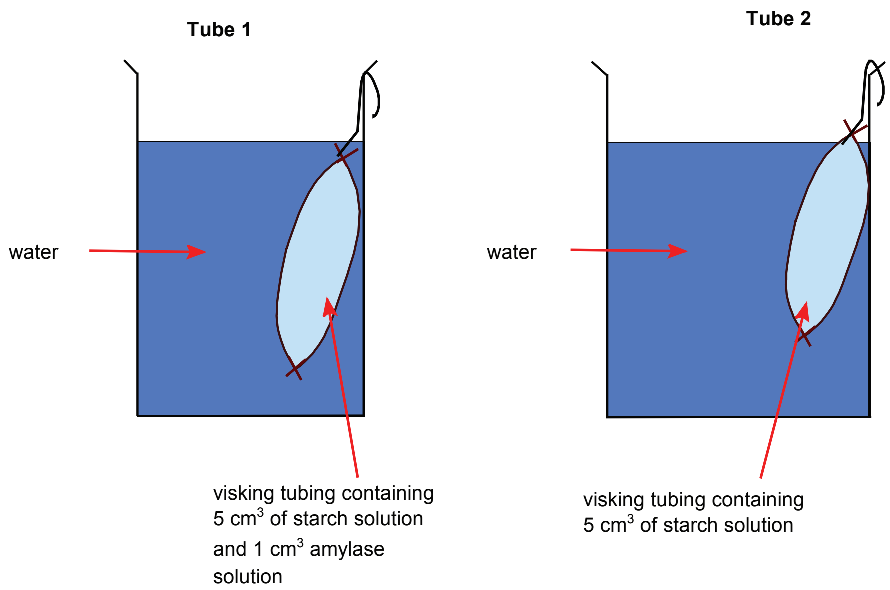
Visking tubing is non-living and has no blood supply. This means it cannot maintain a steep concentration gradient for diffusion.

Be careful! Visking tubing is also used to model osmosis.

If the question is about digestion then the tubing is modelling diffusion not osmosis.

Experiment to show digestion

1. Set up the apparatus as shown in the diagram below:



Notice: **Tube 1** contains starch and amylase but **Tube 2** contains only starch.

2. Leave to stand at room temperature for ten minutes.

3. Test the solution inside and outside the beakers for starch with iodine solution and glucose with Benedict's solution.

Expected results

	Tube 1		Tube 2	
	Inside	Outside	Inside	Outside
starch present	Yes	No	Yes	No
glucose present	Yes	Yes	No	No

Explanation

There is no starch outside the Visking tubing in either case. Starch is too large to pass through the Visking tubing.

Glucose is present in the solution containing amylase, but not in the solution that doesn't contain amylase. Amylase is responsible for breaking the starch down into glucose.

Glucose is also outside **Tube 1**. Glucose is small enough to pass through the Visking tubing into the water.

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

TEST YOURSELF

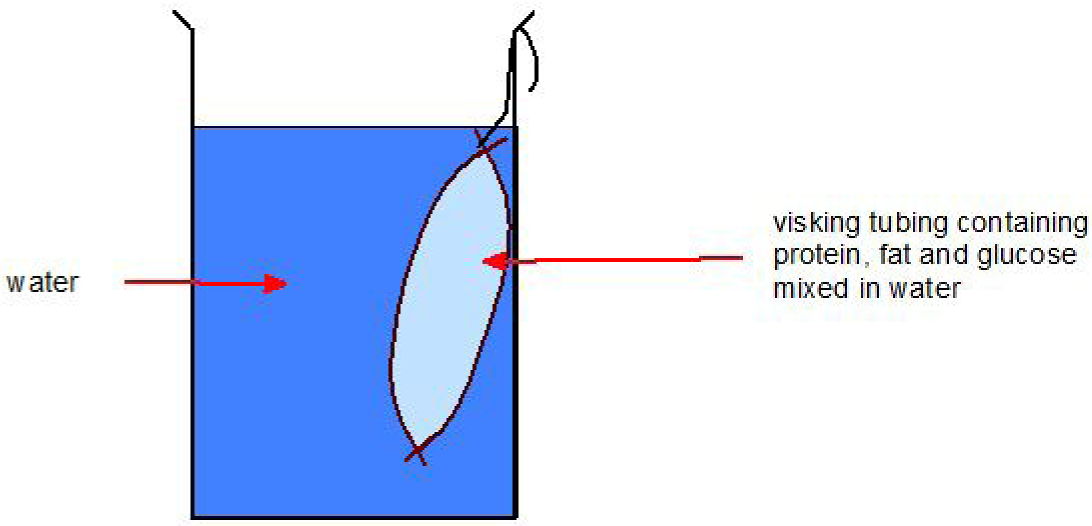
1. Glucose can be tested for using:

A iodine solution **B** biuret reagent **C** Benedict's solution

2. If iodine solution is added to starch, it will:

A not change
B gradually turn from blue to brick red
C turn blue-black

3. An experiment was set up in which a mixture of protein, fat and glucose were mixed in water and put inside the visking tubing. The tubing was left standing in a beaker of water for 1 day.



Next day, the contents of the beaker was tested for each of the food substances that was originally put in the visking tubing.

When the water in **the beaker** was tested, it was found to contain:

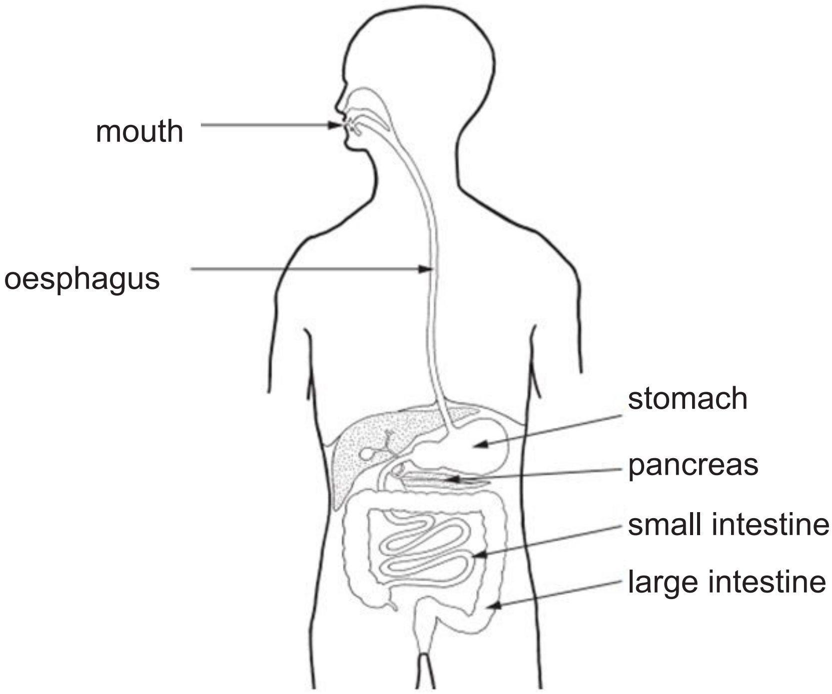
A protein and glucose **B** only glucose **C** only protein

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

PRACTICE QUESTIONS

1. The diagram shows the digestive system.



(a) Write down the name of the organ from the diagram that best fits each description below.

(i) The organ that secretes lipases, proteases and carbohydrases. [1]

……………………………………………………………………………………..

(ii) The organ where fats are digested to fatty acids and glycerol. [1]

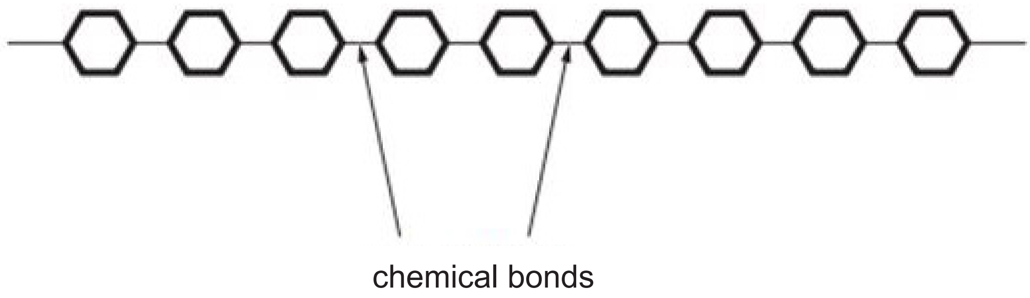
………………………………………………………………………………………..

(iii) The organ where the digestion of starch begins. [1]

……………………………………………………………………………………….

PRACTICE QUESTIONS - CONTINUED

(b) The diagram below represents a short length of a starch molecule.



(i) Name the type of enzyme that breaks the chemical bonds in the starch molecule. [1]

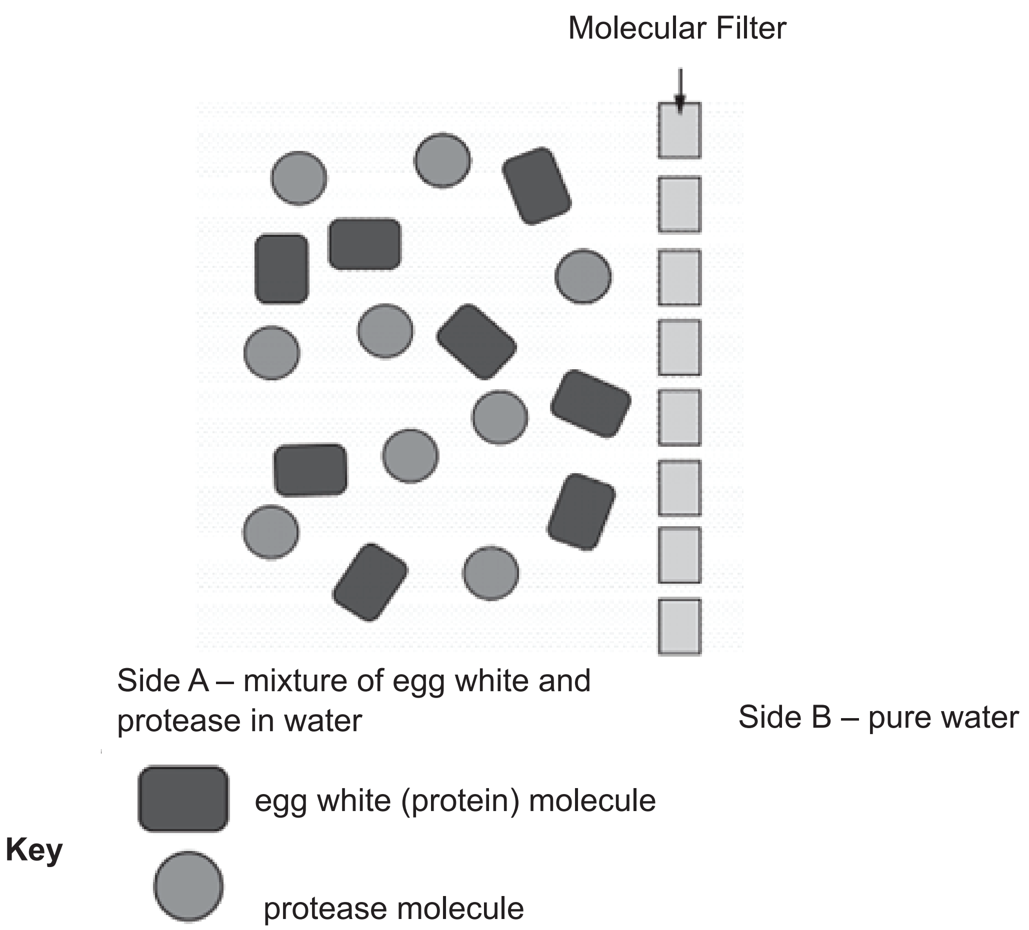
……………………………………………………………………………………..

(ii) Name the end product of starch digestion. [1]

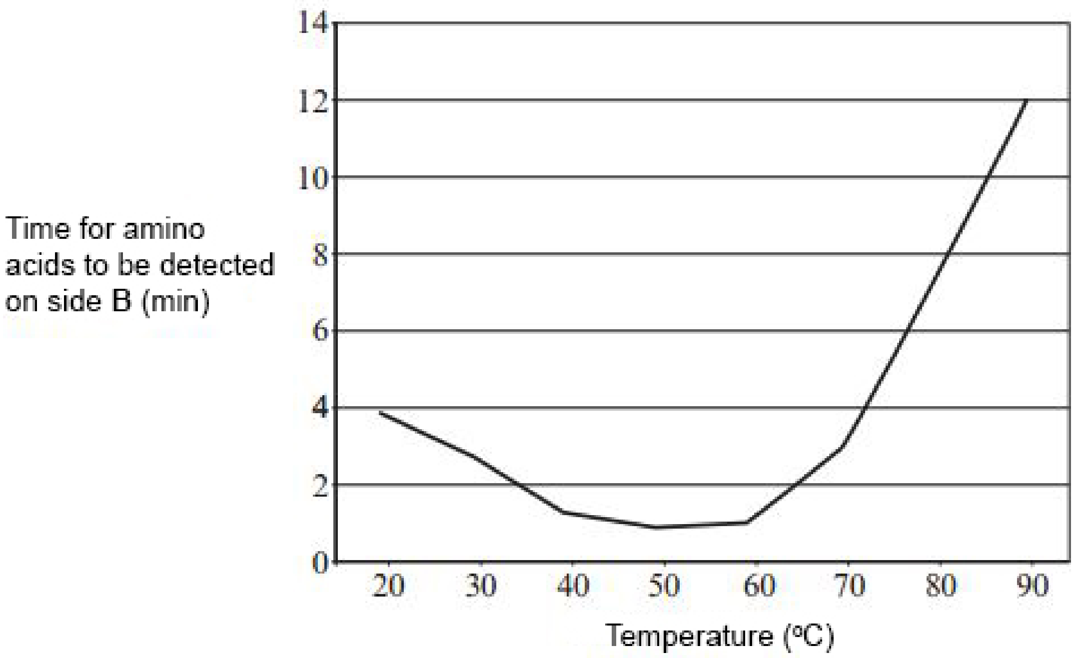
………………………………………………………………………………………..

PRACTICE QUESTIONS

2. An experiment was set up to investigate the effect of temperature on the action of protease enzyme. A mixture of egg white (protein) and protease in water was separated from pure water by a molecular filter.



The experiment was carried out at different temperatures and the time taken for amino acids to be detected in the pure water on side B was noted. The results are shown in the graph overpage.



(a) Explain fully why the time taken for the amino acids to appear in the pure water at 40°C was less than at 20°C. **[3]**

....

....

....

....

(b) Explain fully why the time taken for the amino acids to appear in the pure water at 50°C was less than at 90°C. **[2]**

....

....

....

....

3. **(a)** Megan tested samples of blood plasma for the presence of three food molecules.

Complete the table below to show the expected results. **[2]**

reagent used	molecule tested for	colour of reagent	colour of plasma after testing	positive result = ✔ negative result = **X**
……………	glucose	…………	brick red	✔
…………….	starch		brown	**X**
Biuret	…………….	….………..	violet	………………..….

(b) The table shows that starch is **not** present in the blood plasma, even though starch is part of the human diet.

Explain why starch is not found in the plasma. **[3]**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

HIGHER TIER ONLY

4. In salt marshes, the soil is covered by sea water at high tide. Specially adapted plants (Halophytes) are able to survive in these areas of high salt concentration.

They survive because the contents of their cells have high concentrations of salts.

(a) Name the process by which these plants can take salts into their cells against a concentration gradient. **[1]**

....

(b) Name two chemicals which are needed to release energy for this process to occur. **[2]**

....

....

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

TEST YOURSELF - **ANSWERS FOR UNIT 1.1**

Cells and organisation

1. C
2. B
3. B
4. C
5. C

Transport in cells

1. down …high … low … diffusion … water
2. D
3. B

Respiration

1. C
2. A
3. C
4. A

The respiratory system

1. **a)** contract **b)** contracts, flattens
2. A
3. **A:** bronchioles **B**: intercostal muscle **C**: diaphragm **D**: trachea **E**: bronchus **F:** alveoli

Digestion

1. **A** - gall bladder **B** - small intestine **C** - large intestine **D** - stomach
2. C
3. peristalsis, contraction, relaxation
4. B

Energy and Life (Unit 1.1)

Obtaining the materials for respiration (specification 1.1.2)

Enzymes

1. A
2. B
3. B
4. C

The digestion of starch, fats and proteins

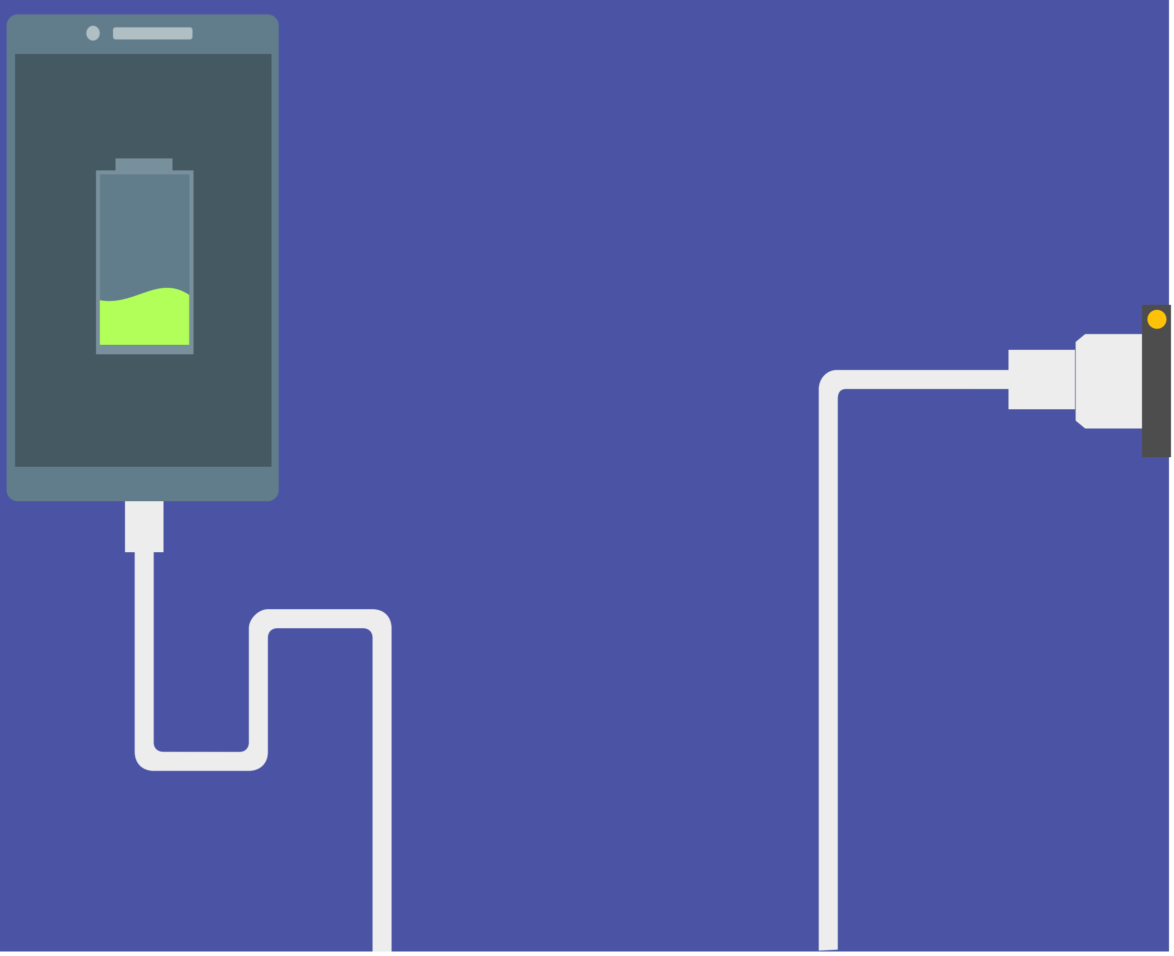
1. W-protein X-glucose Y fats Z lipase
2. 2,4,3,1

Food tests

1. C
2. C
3. B

Modern life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)



Modern life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)

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 400 J 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:

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

$$\text{efficiency} = 60\%$$

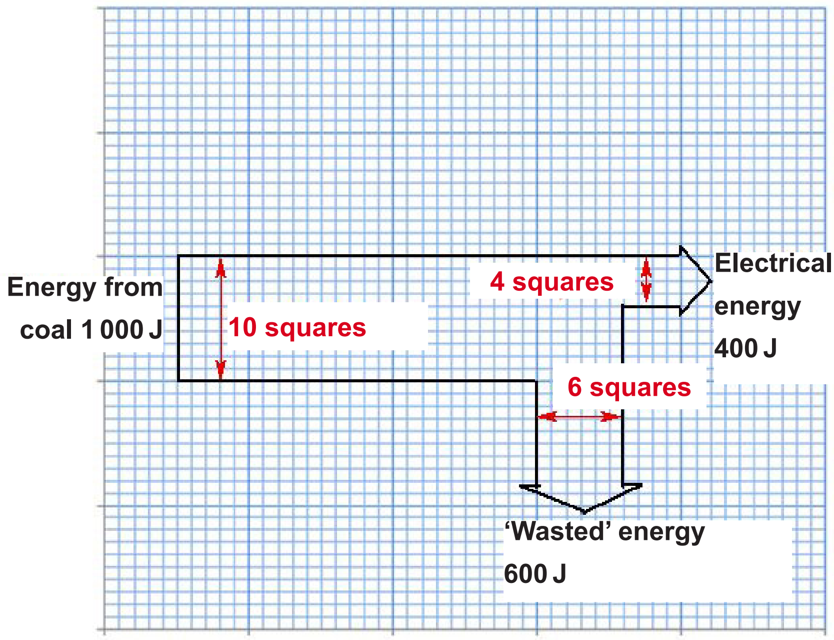
Coal fired power station
eye35.pix / Alamy Stock Photo

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.

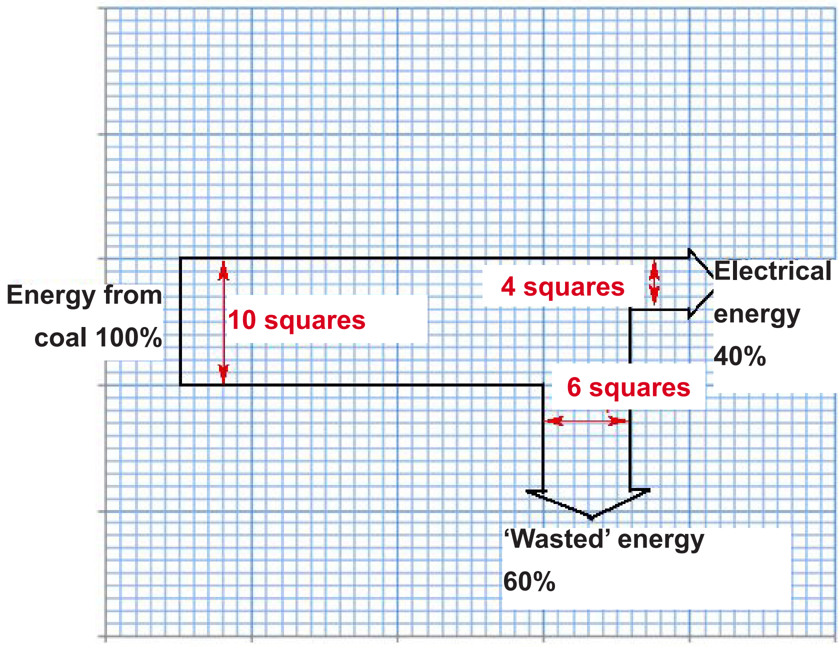
Sankey diagrams

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.



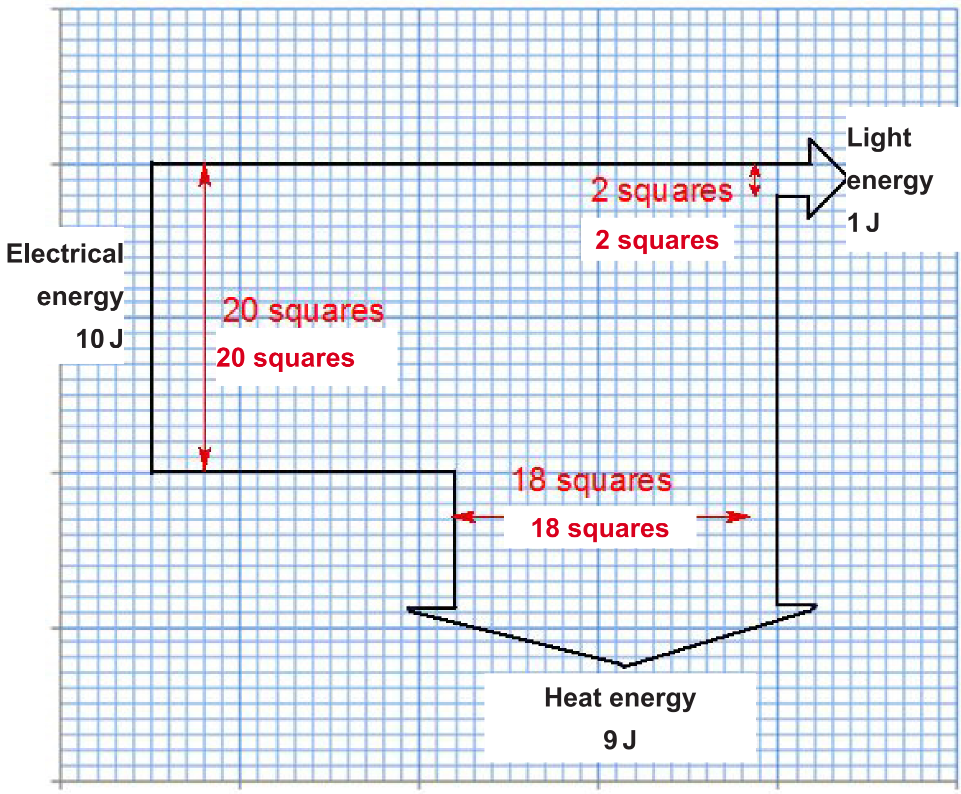
We can draw Sankey diagrams for any process.

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.

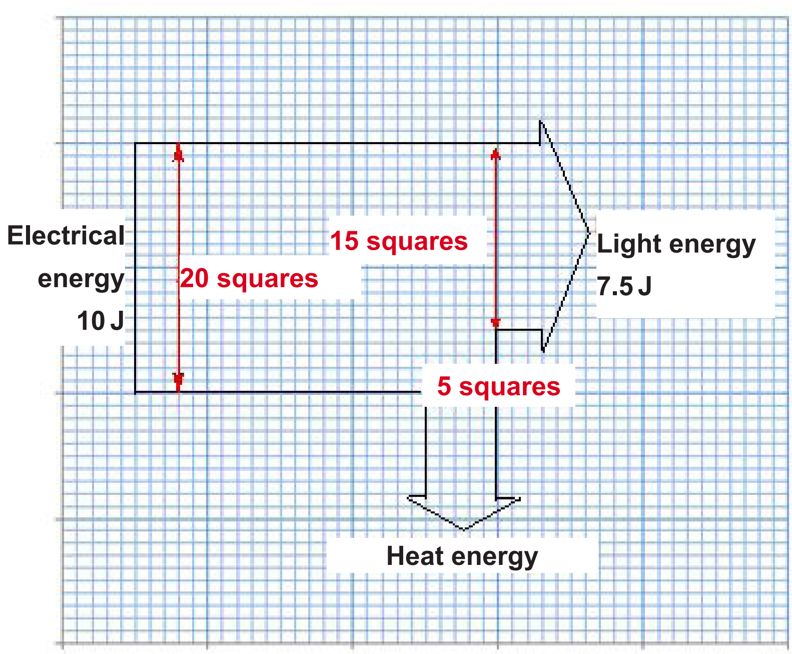
For every 10 J of electrical energy supplied to the lamp only 1 J is transferred to the surroundings as light energy. The remainder, 9 J (10 J – 1 J) is transferred to the surroundings as heat energy.

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

Modern life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)

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 life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)

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 life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)

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.

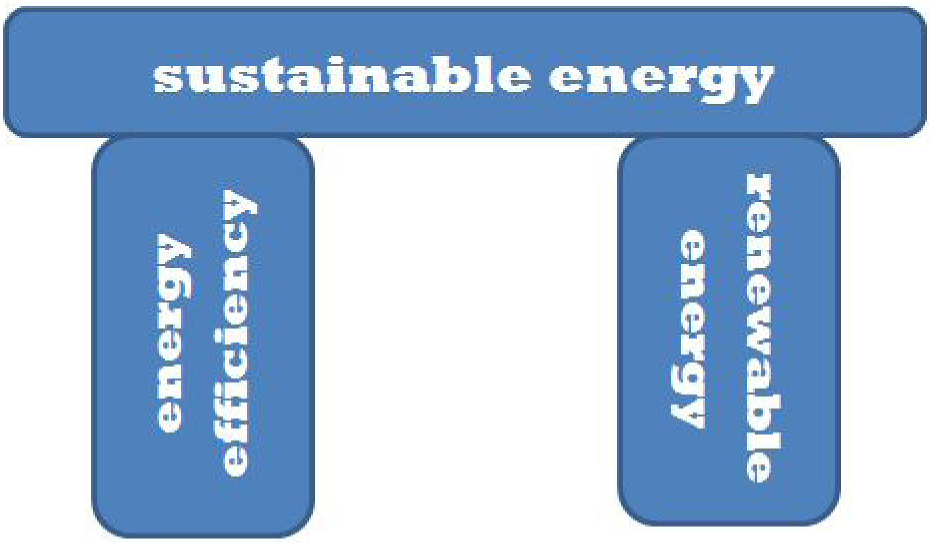
Sustainability and energy

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.



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 1.2.2.**

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 (see topic **2.1.3** for more information). 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**

Modern life and energy (Unit 1.2)

Underpinning energy concepts (specification 1.2.1)

TEST YOURSELF

1. State two pillars of sustainable energy.

   A fossil fuels and energy efficiency
   B renewable energy and energy efficiency
   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 life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

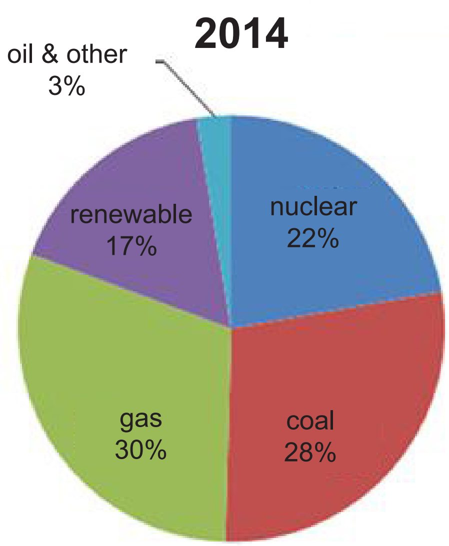
Modern life and energy (Unit 1.2)

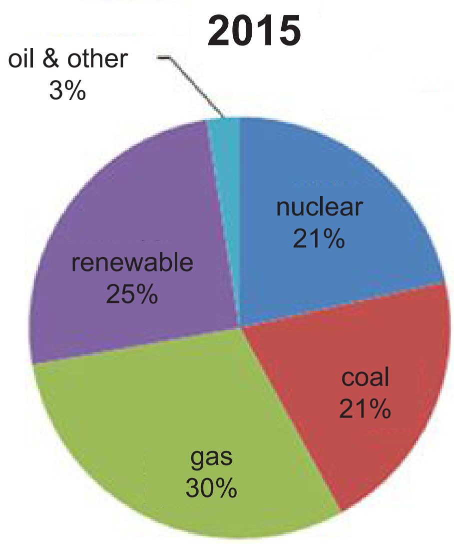
Generating electricity (specification 1.2.2)

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 first major country to do so. It intends to fill the capacity gap largely with new gas and nuclear plants.

Coal fired power station
nico_65 / gettyimages

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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-fired	Oil-fired	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.

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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 (gCO2/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.

Modern life and energy (Unit 1.2)

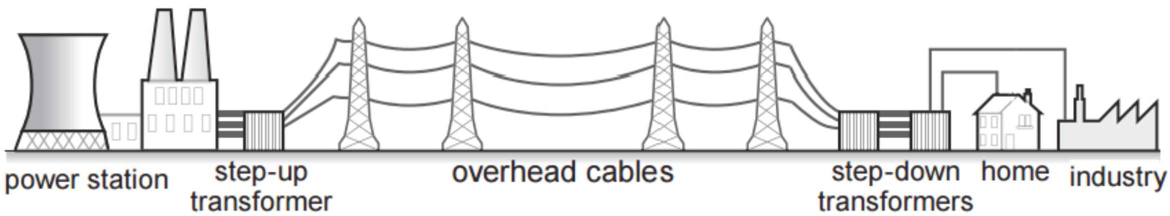
Generating electricity (specification 1.2.2)

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 efficiently

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.

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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).

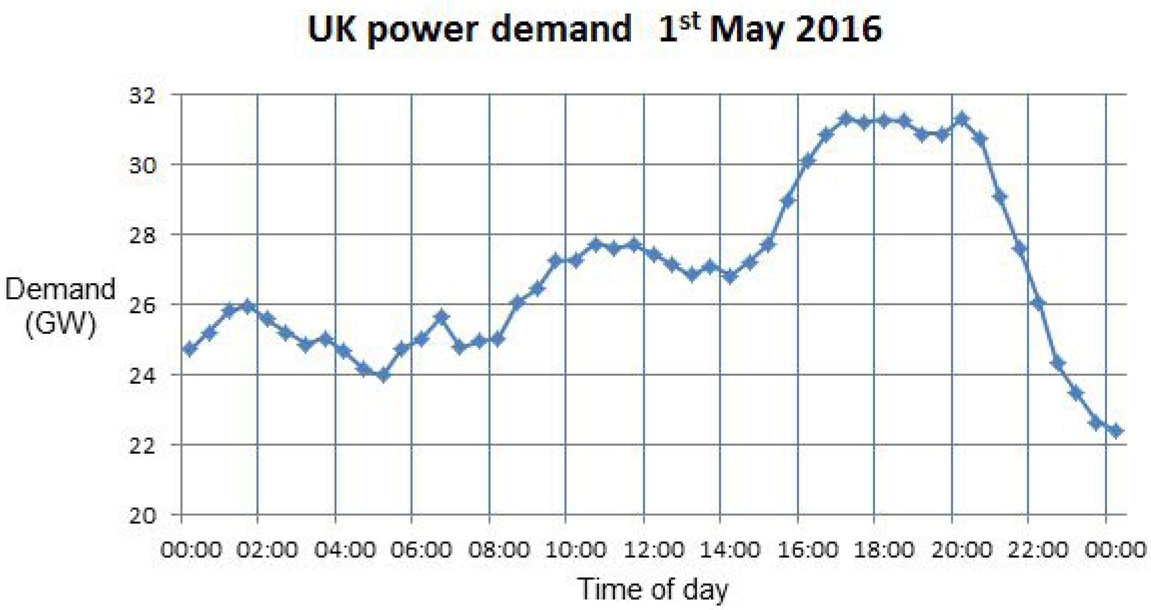
These high voltages are too dangerous to use in the home, so **step-down transformers** are used locally to reduce the voltage to safe levels.

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.

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-fired	oil-fired	gas turbine	pumped storage
start-up time	48 h	6 h	12 h	2 min	10 s

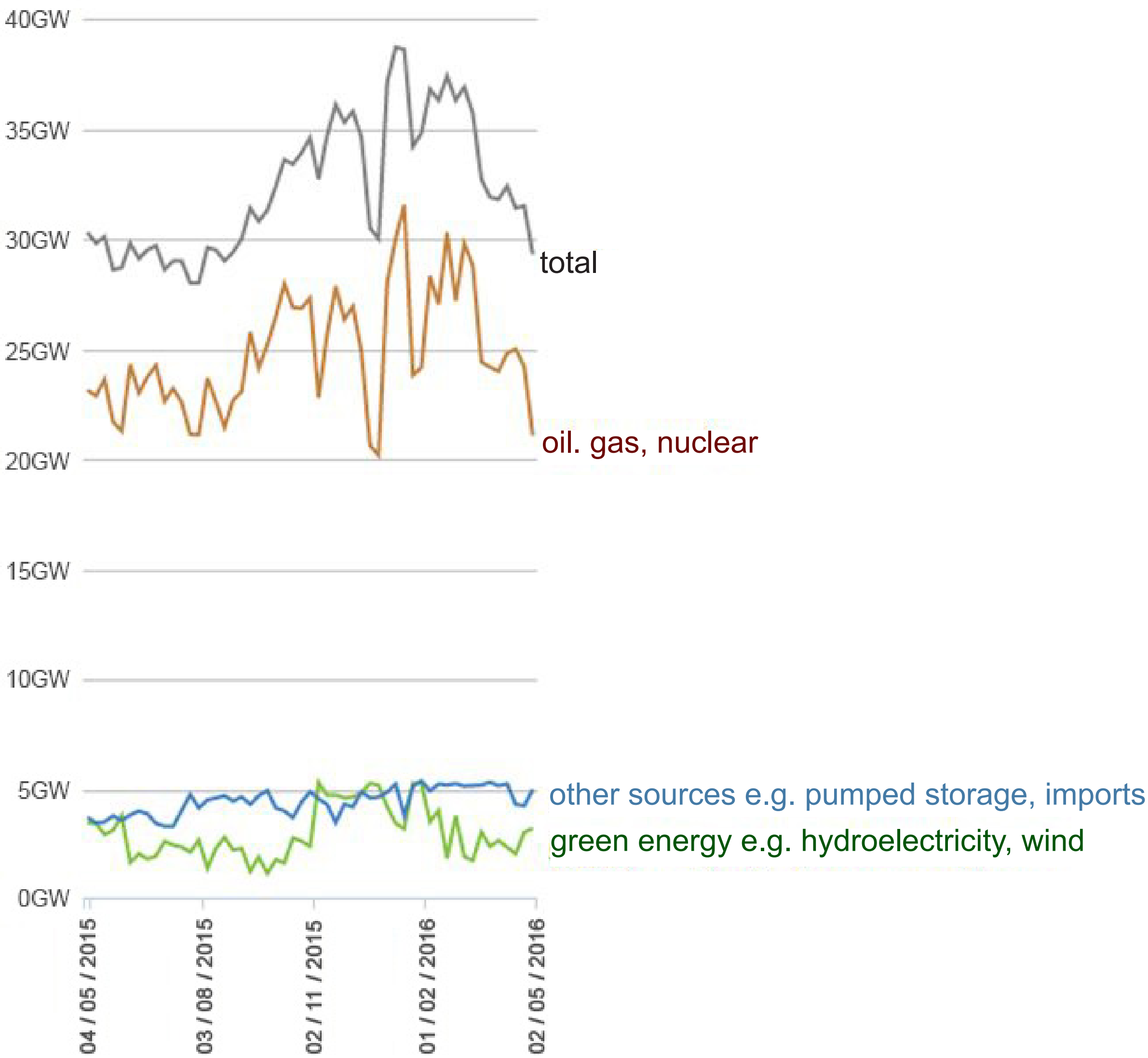
The National Grid uses different sources of energy in order to ensure that there is an uninterrupted supply of electricity. The UK also has agreements with some other countries which allows for the import or export of electricity when necessary. For example, a 2 GW bidirectional cable links the UK National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

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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



Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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.

Solar panels
Steve Allen Travel Photography / Alamy Stock Photo

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.

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

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 fired

Modern life and energy (Unit 1.2)

Generating electricity (specification 1.2.2)

PRACTICE QUESTIONS

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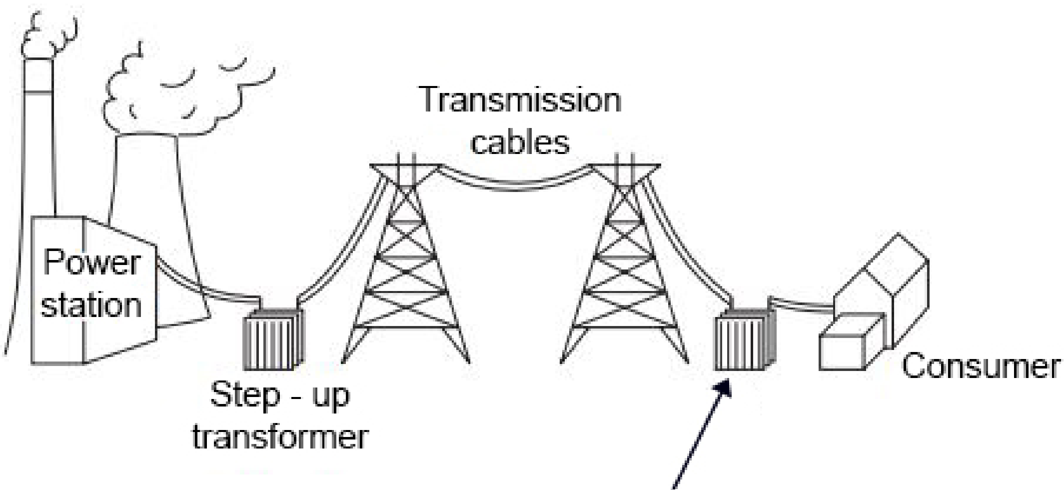
1. The diagram shows how electricity is distributed from a power station to consumers.



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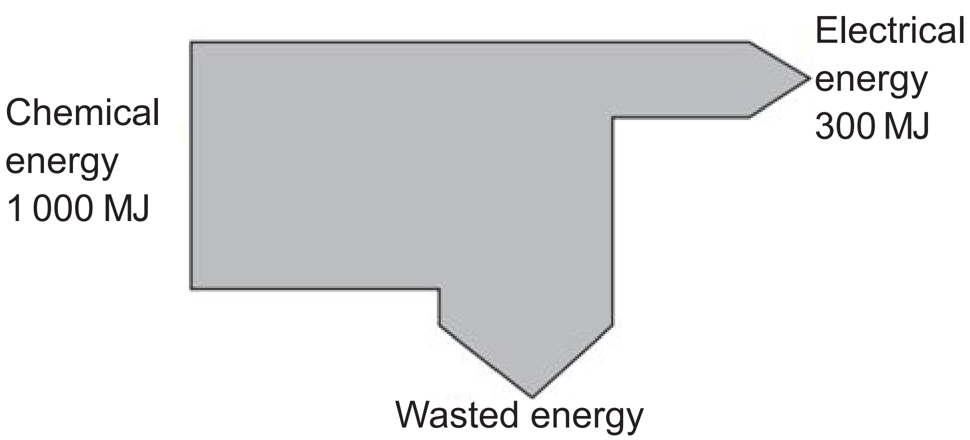
(a) Fill in the missing label on the diagram. **[1]**

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

Use the equation:

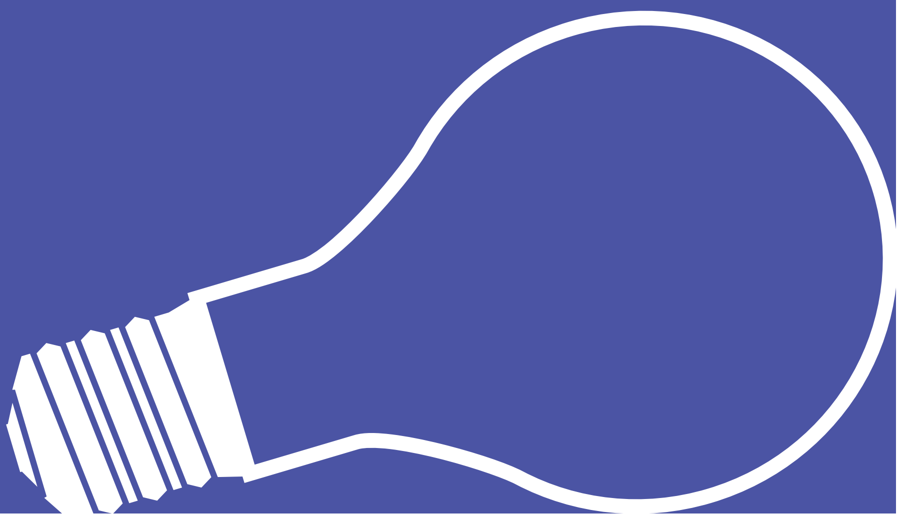
power = voltage × current

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 life and energy (Unit 1.2)

Making use of energy (specification 1.2.3)



Modern life and energy (Unit 1.2)

Making use of energy (specification 1.2.3)

REDUCING OUR ENERGY DEMANDS

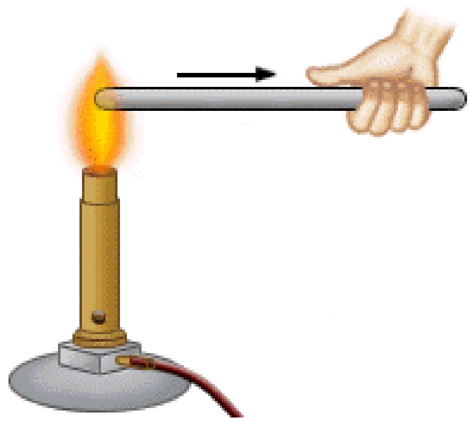
Energy is an expensive commodity and it is important that we do not waste it, either in the home or industry. The production of energy also leads to the formation of greenhouse gases so the more efficiently we use energy, the lower our carbon footprint will be and the smaller our impact on the environment.

Energy transfers

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

Conduction

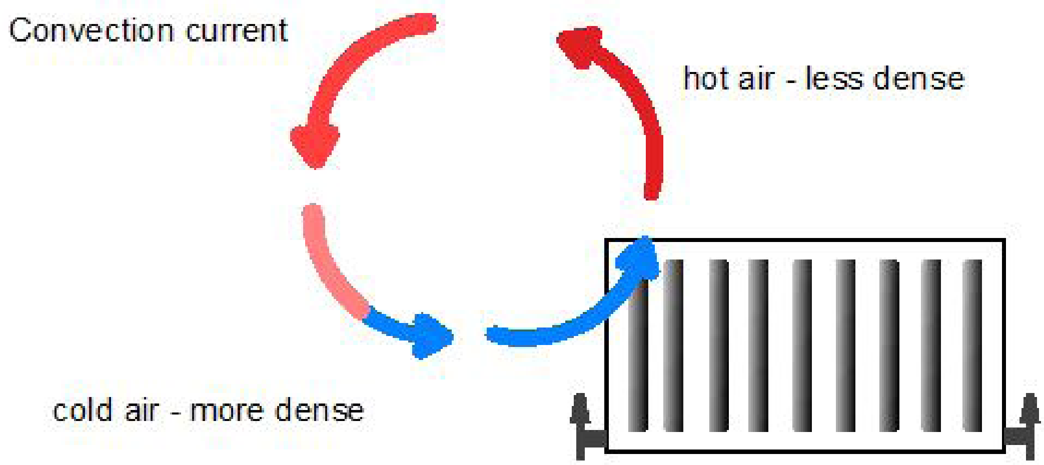
Heat is transferred from one part of a **solid** to another **without** particles moving through the material.



Heat conducted through a metal rod
Unable to trace copyright.
Please contact us if you are the copyright holder.

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 surfaces
- is absorbed best by black, dull surfaces but **not** shiny surfaces.

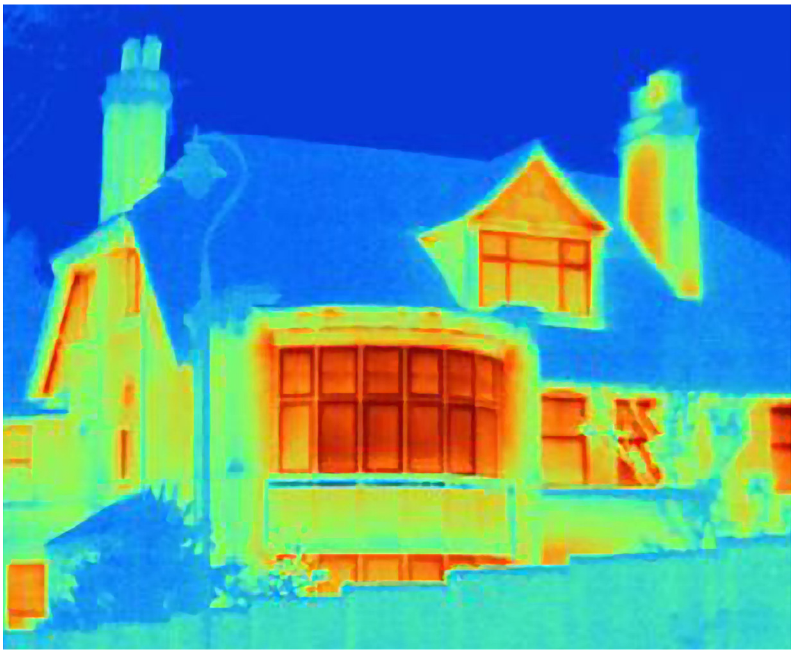
Sand dunes
Nino Marcutti / Alamy Stock Photo

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 windows

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.

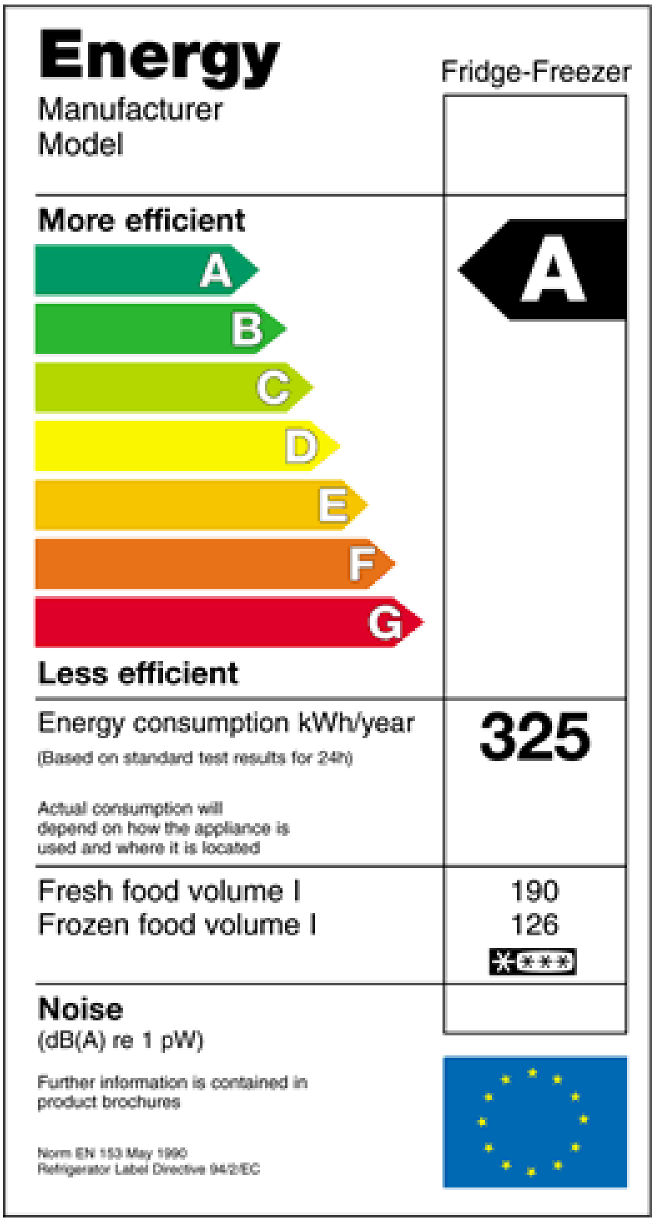
Calculate the payback time.

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

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

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 life and energy (Unit 1.2)

Making use of energy (specification 1.2.3)

Energy efficient bulbs

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

<u>Answer</u>

Incandescent lamp

unit 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 poorer. 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 life and energy (Unit 1.2)

Making use of energy (specification 1.2.3)

TEST YOURSELF

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
efficiency	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 12 000 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 life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

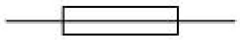
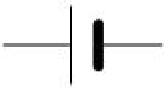
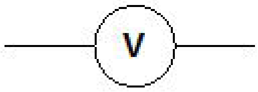
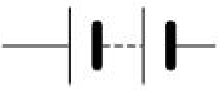
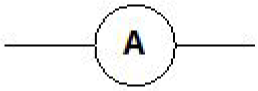
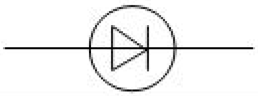
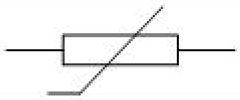
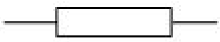
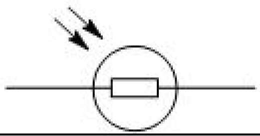
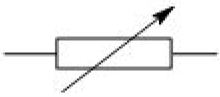
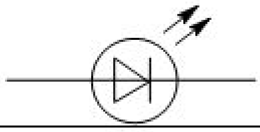
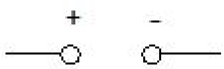
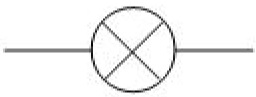
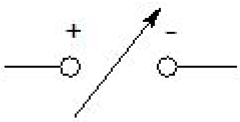
Modern life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

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 life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

Making a circuit

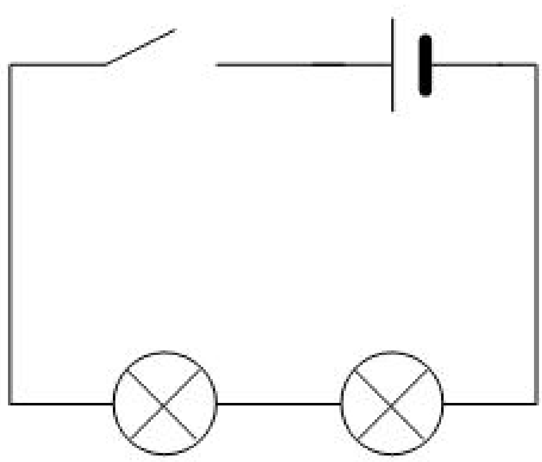
An electric current is a flow of electrical charge. The charge only flows if there is a complete circuit.

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

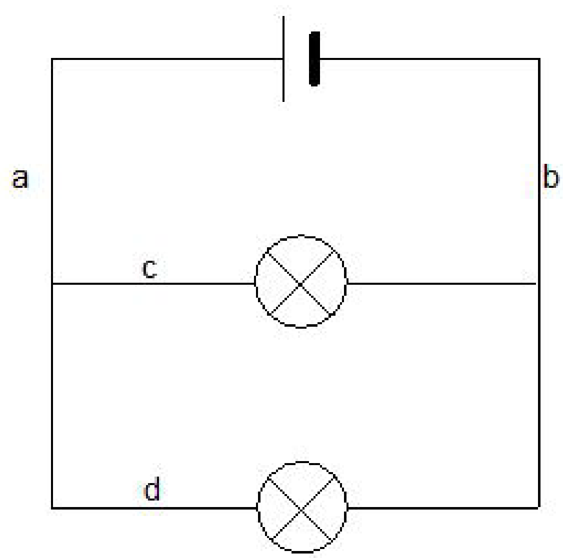
If either lamp in the circuit above breaks then this breaks the circuit and no current will be able to pass through the second lamp.

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.**

Modern life and energy (Unit 1.2)

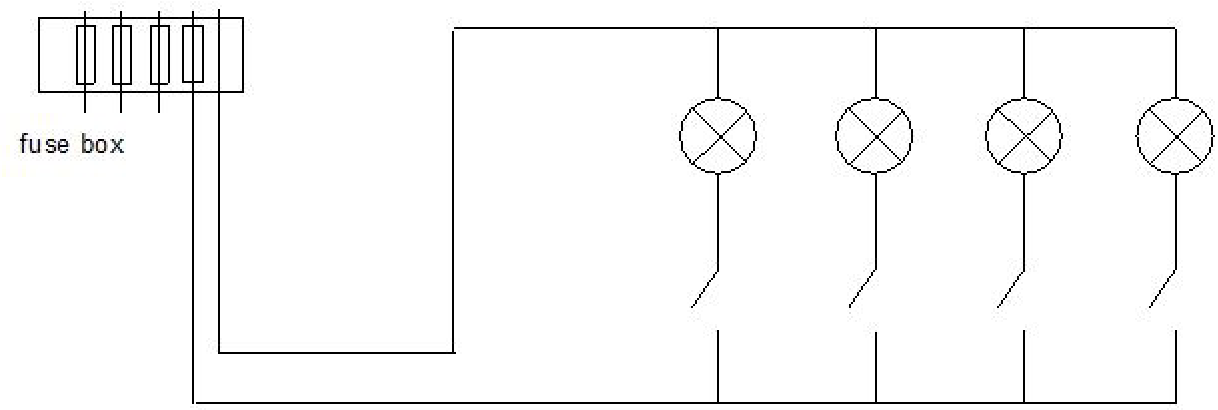
Building electric circuits (specification 1.2.4)

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 other 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

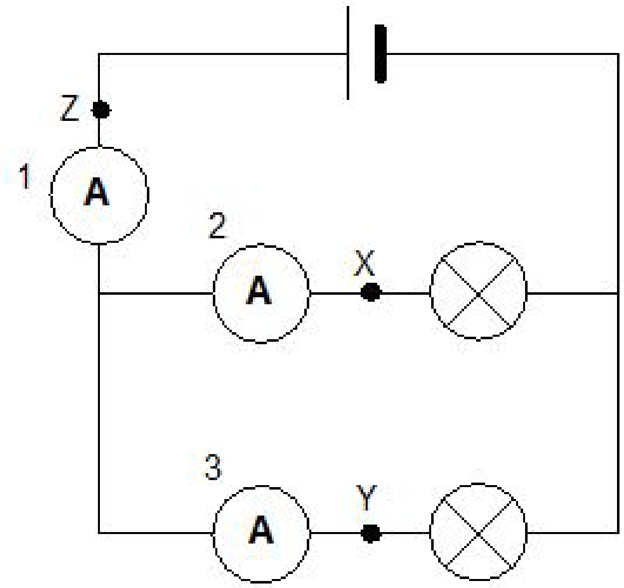
Electrical **current** is measured in amperes (amps), A.

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

Modern life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

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.

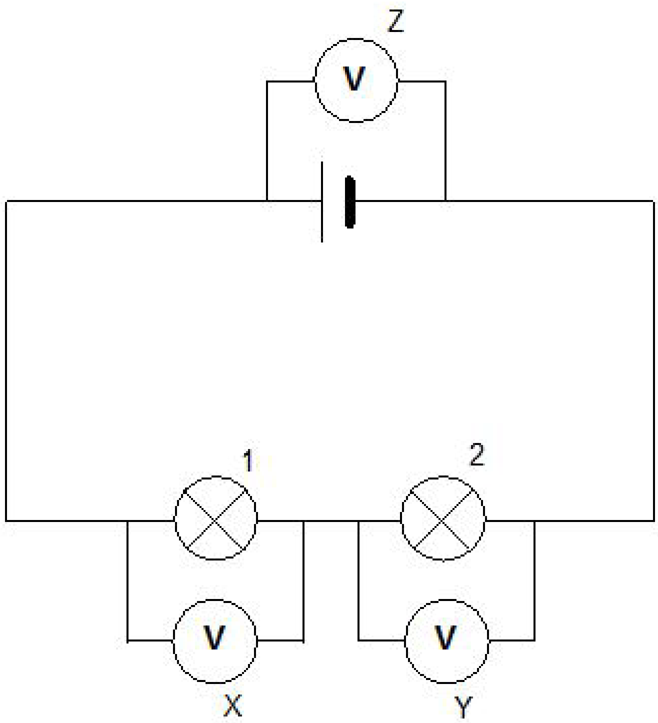
Voltmeters must be connected **in parallel** to the component.

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:

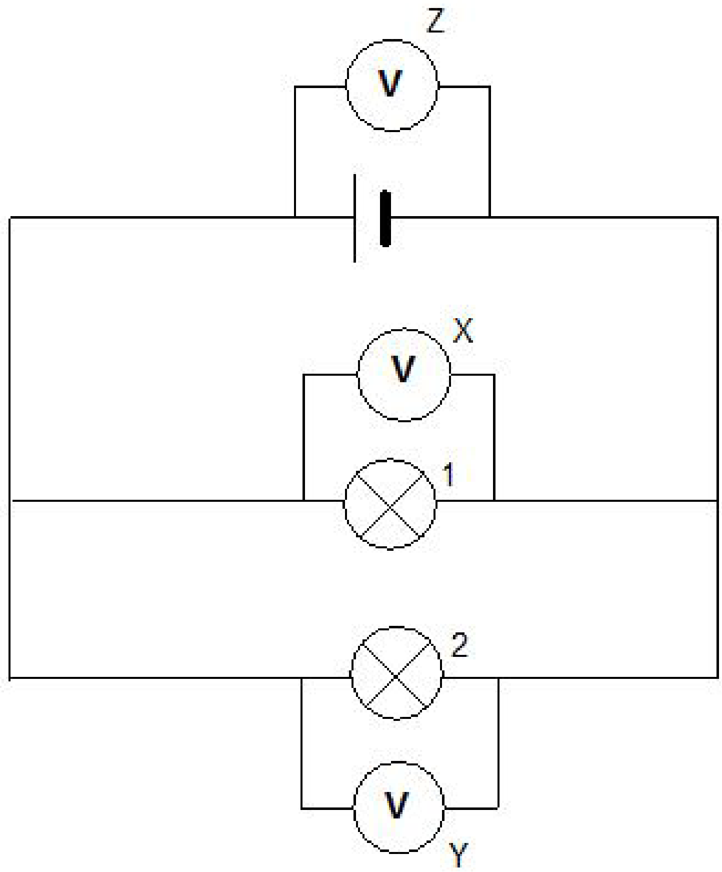
- voltmeter **X** is placed in parallel with lamp 1. It measures the voltage drop (V_1) across lamp 1.
- voltmeter **Y** is placed in parallel with lamp 2. It measures the voltage drop (V_2) across lamp 2.
- voltmeter **Z** measures the total voltage (V_T) supplied by the cell.
- In this series circuit,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



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:

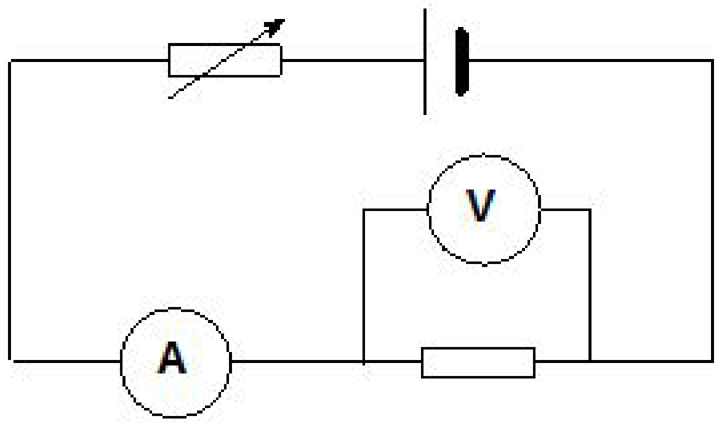
$$I \propto \frac{1}{R}$$

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

Investigating current changes with voltage

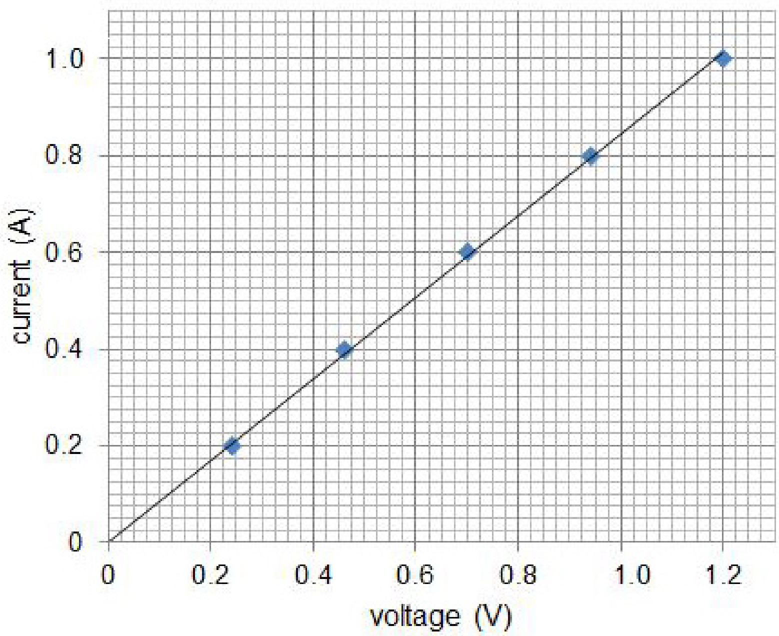
The resistance of connecting wires can be assumed to be so small that it can be ignored.

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



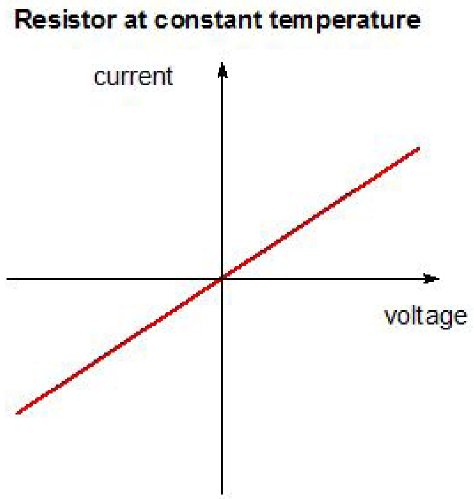
You can also use this circuit to investigate other types of components by swapping the fixed resistor for, e.g. a filament lamp or a diode.

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

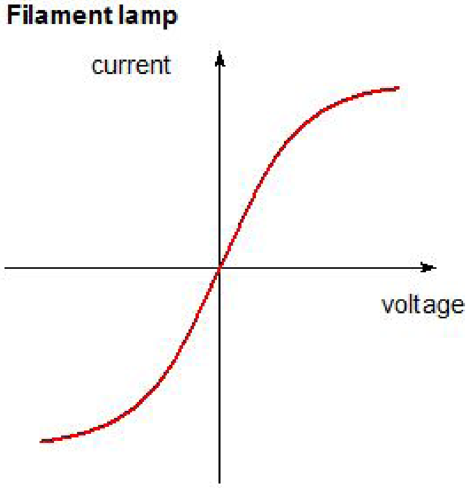
- resistor at constant temperature
- filament lamp
- diode.

Modern life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

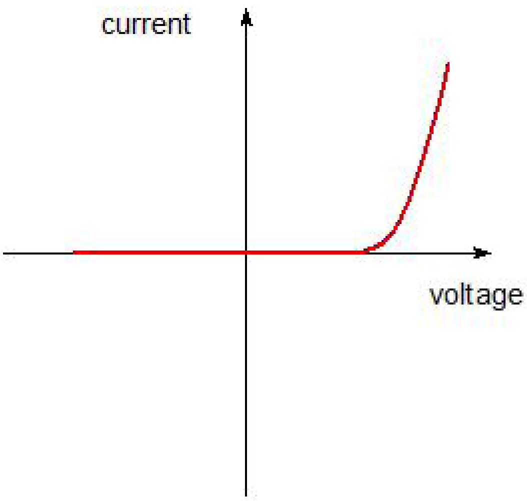


A resistor (at constant temperature) will always give a straight line; the current and voltage are directly proportional to each other. In other words, the resistance of the resistor stays constant.



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 life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

Combining resistors

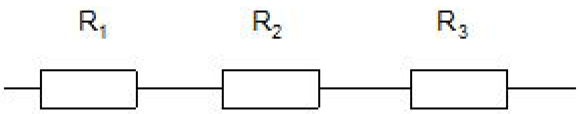
When we add components to a circuit we change the resistance of a circuit.

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.

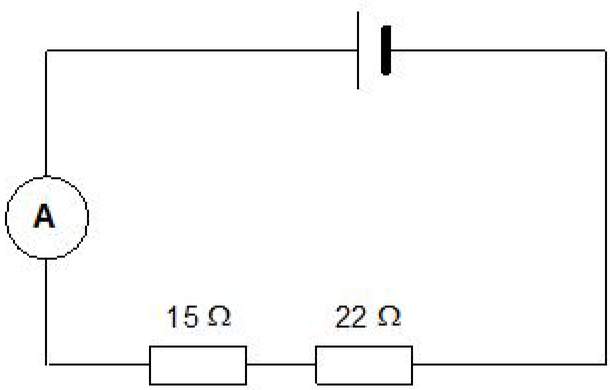
Adding resistors in series

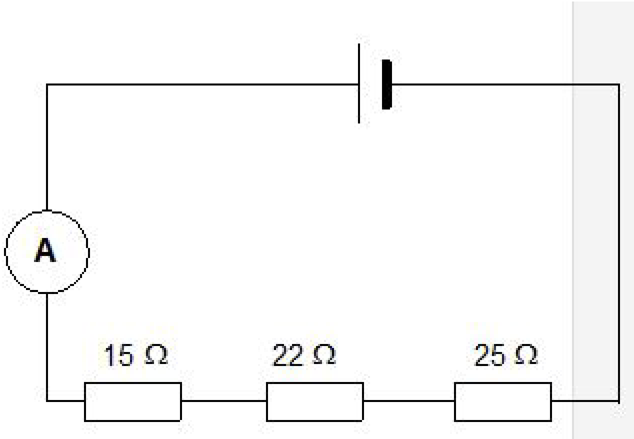
The current will pass through each of the components that are in series.
The total resistance (R_T) = the sum of the separate resistances.
For three resistors in series, R_1, R_2 and R_3



$R_T = R_1 + R_2 + R_3$

Example





Total resistance = 15 + 22 = 37 Ω

Total resistance = 15 + 22 + 25 = 62 Ω

Modern life and energy (Unit 1.2)

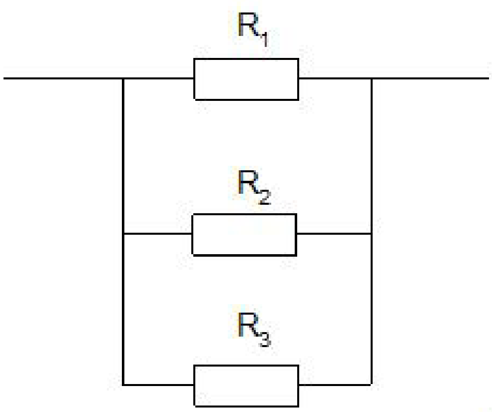
Building electric circuits (specification 1.2.4)

Adding resistors in parallel

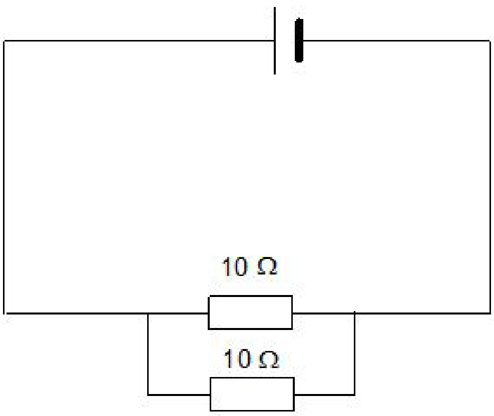
The total resistance falls. The current through each resistor will be the same as if it were the only component but there are now more ways that the current can pass through the circuit. This means the total current is larger.

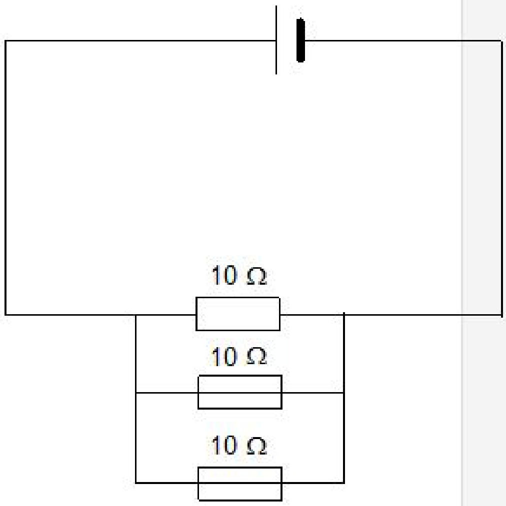
Finding the total resistance is a little more difficult. For three resistors in parallel, the total resistance, R_T can be calculated using:

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



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 = current² × 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: $R = \dfrac{V}{I}$

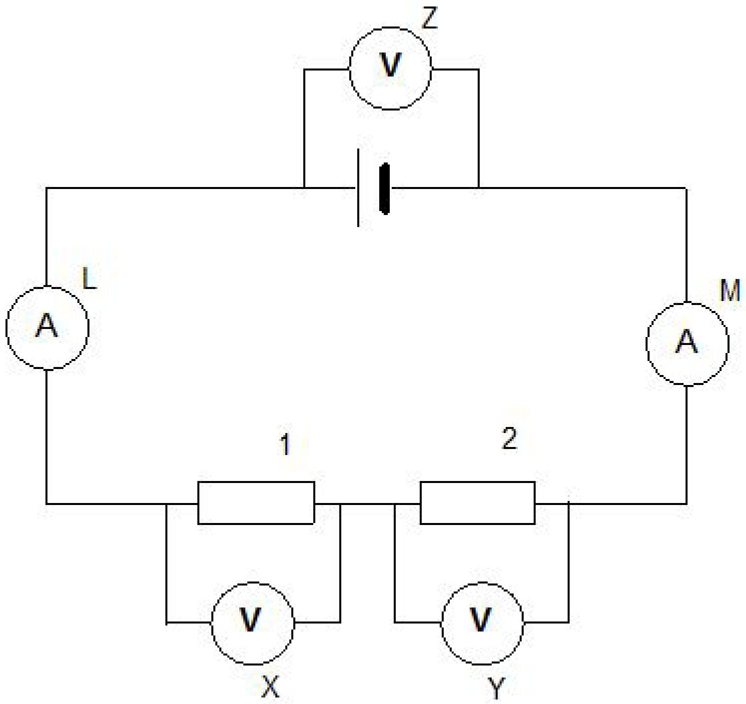
$$R = \frac{6}{0.5} = 112\ \Omega$$

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

$P = IV$

$P = 0.3 \times 12 = 3.6\text{ W}$

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.

$P = I^2R$

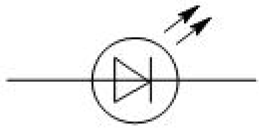
$P = 0.5^2 \times 20 = 5$ W

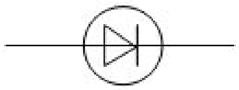
Modern life and energy (Unit 1.2)

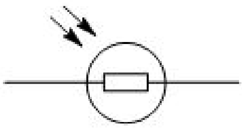
Building electric circuits (specification 1.2.4)

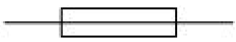
TEST YOURSELF

1. The symbol for a diode is:

A 

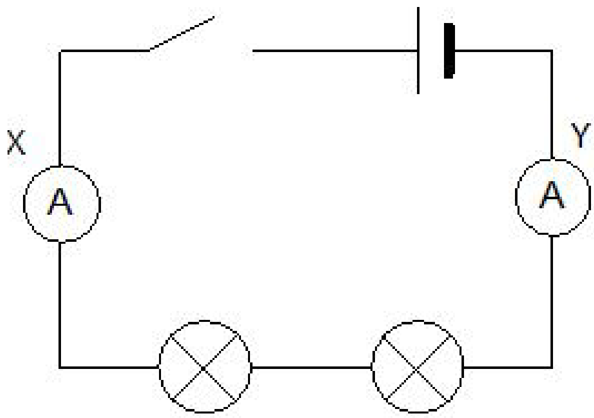
B 

C 

2.  is the symbol for a:

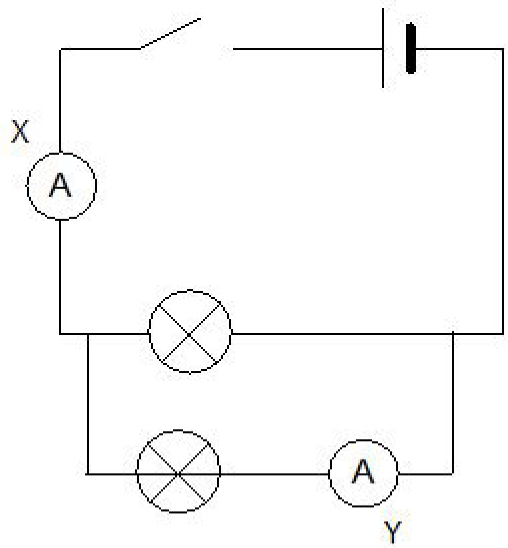
A resistor
B thermistor
C fuse

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:

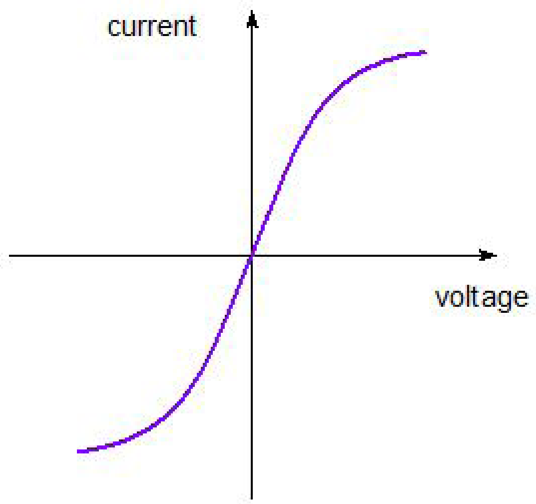


A the same as the reading on ammeter X
B smaller than the reading on ammeter X
C larger than the reading on ammeter X

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

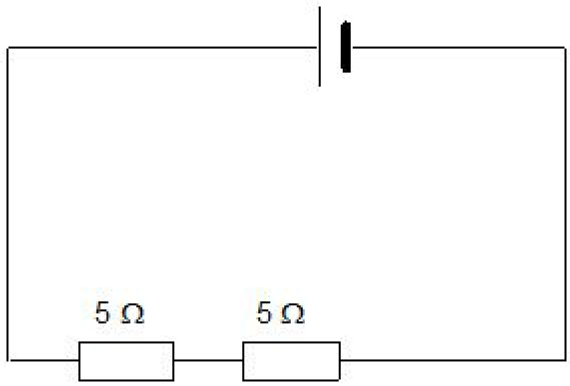
A next to the cell
B in parallel to the component
C in series with the component

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



A diode
B resistor
C filament lamp

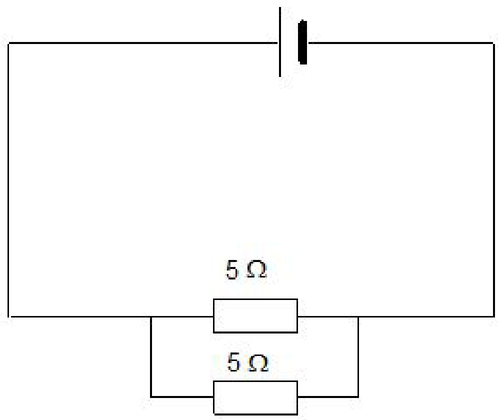
7. Calculate the total resistance for the circuit below.



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 $P = IV$

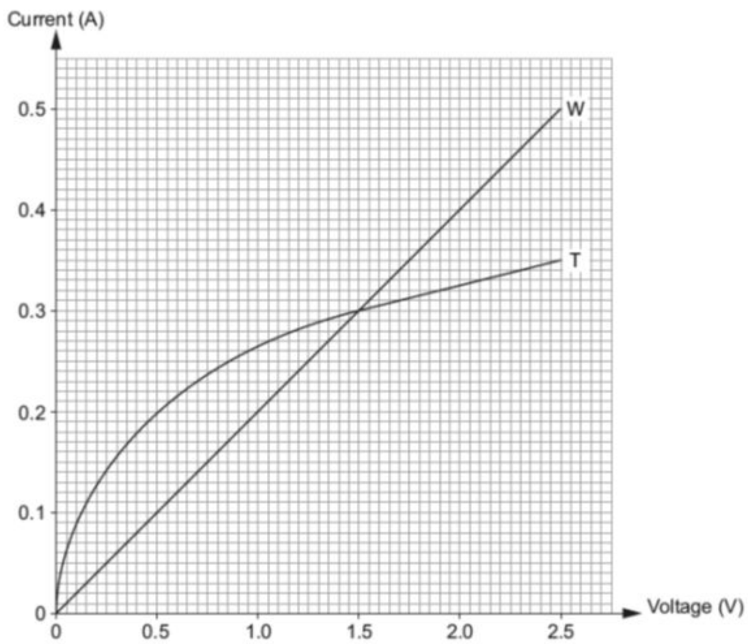
A 0.3 Ω
B 30 Ω
C 2.7 Ω

Modern life and energy (Unit 1.2)

Building electric circuits (specification 1.2.4)

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]**

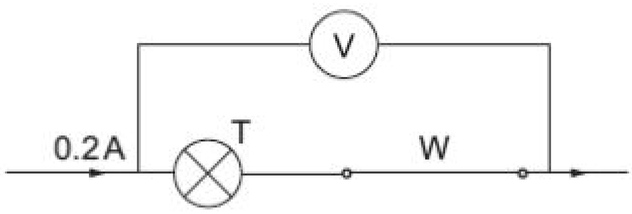
current = …………… A

(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 1.2

Energy and efficiency

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 1.3)

Obtaining clean water (specification 1.3.1)

Obtaining resources from our planet (Unit 1.3)

Obtaining clean water (specification 1.3.1)

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 1.3.2). 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 1.3)

Obtaining clean water (specification 1.3.1)

TEST YOURSELF

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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 clean water (specification 1.3.1)

COMPOUNDS

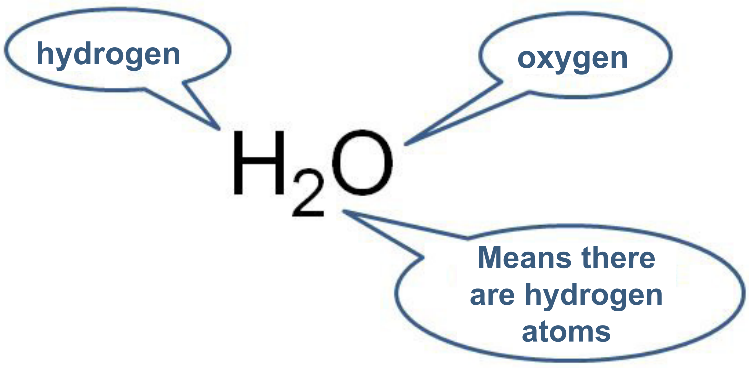
Most chemicals we meet are compounds.

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 1.3)

Obtaining clean water (specification 1.3.1)

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

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.

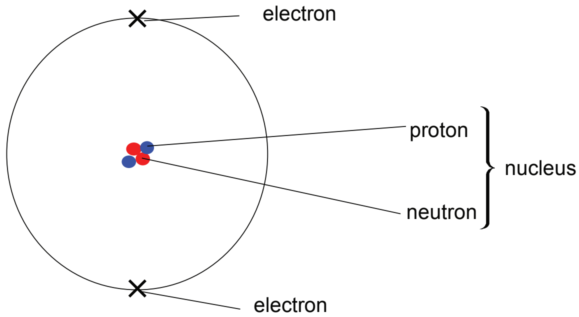
An example: helium

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.

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Obtaining clean water (specification 1.3.1)

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 1.3)

Obtaining clean water (specification 1.3.1)

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	

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ELECTRONIC STRUCTURE

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

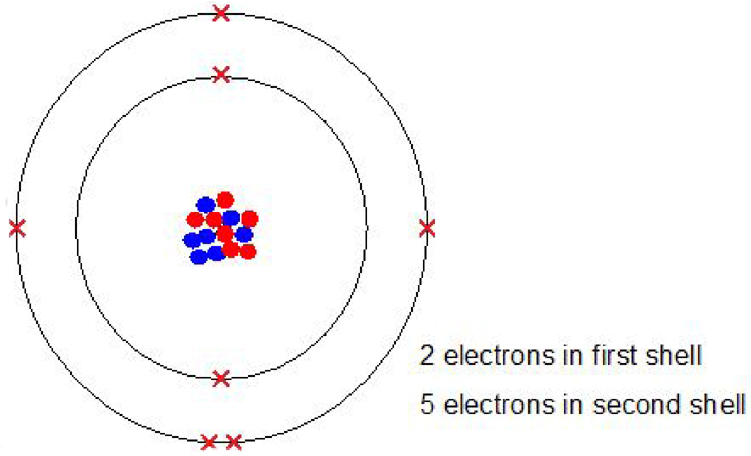
Each shell can contain a maximum number of electrons:

- 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.

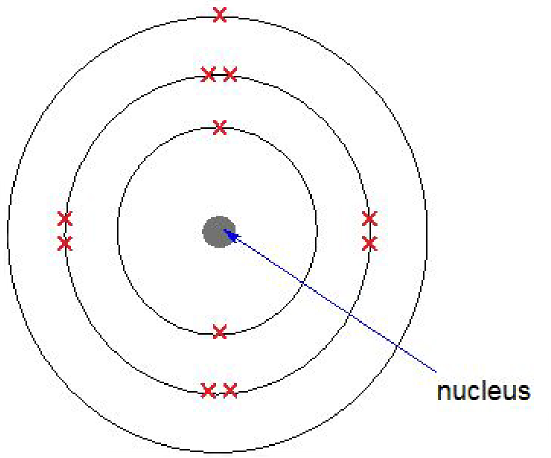
This means it contains 7 protons in the nucleus and 7 electrons in the shells around the nucleus.



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 1.3)

Obtaining clean water (specification 1.3.1)

TEST YOURSELF

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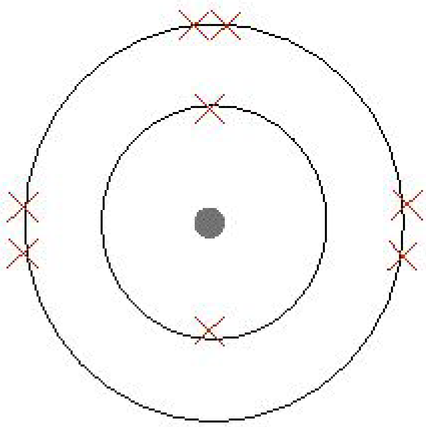
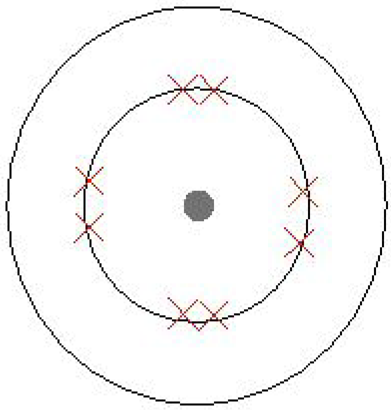
1. The electronic configuration of oxygen (atomic number 8) is:

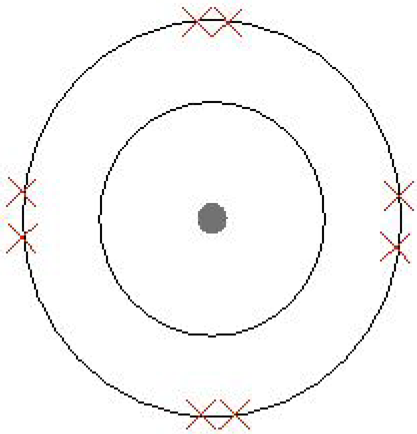
A



B

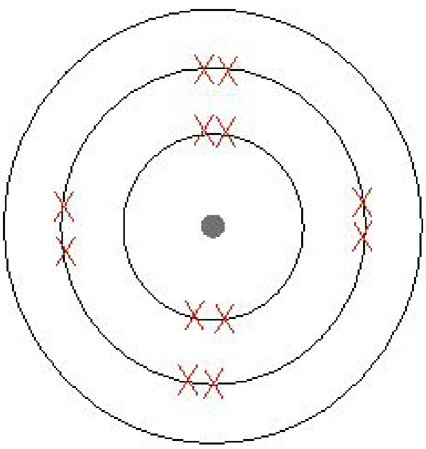


C

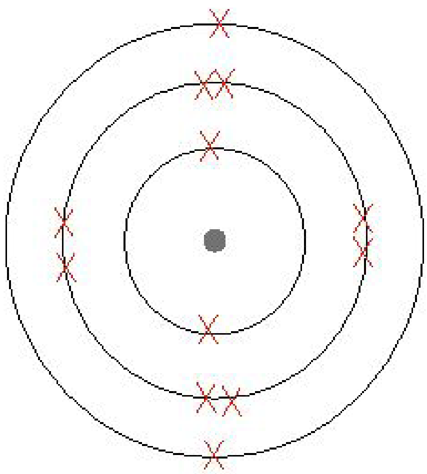


2. The electronic configuration of magnesium (atomic number 12) is:

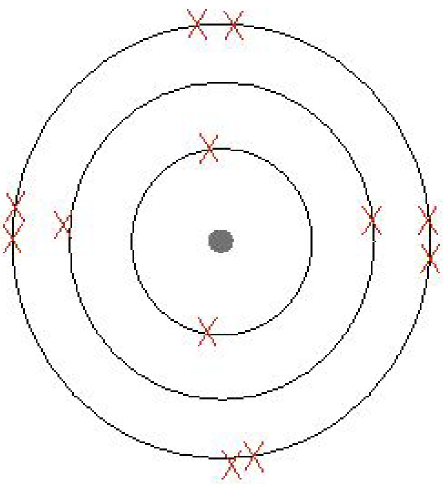
A



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

Obtaining clean water (specification 1.3.1)

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 1.3)

Obtaining clean water (specification 1.3.1)

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 Na^{+}** ions for every **one 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 Al^{3+}** ion for every **three 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 1.3)

Obtaining clean water (specification 1.3.1)

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 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 1.3)

Obtaining clean water (specification 1.3.1)

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.

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!

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

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 1.3)

Obtaining clean water (specification 1.3.1)

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.

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

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.

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.

Cheddar Caves, Somerset
David Wall / Alamy Stock Photo

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.

Obtaining resources from our planet (Unit 1.3)

Obtaining clean water (specification 1.3.1)

From agriculture

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.

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

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 1.3)

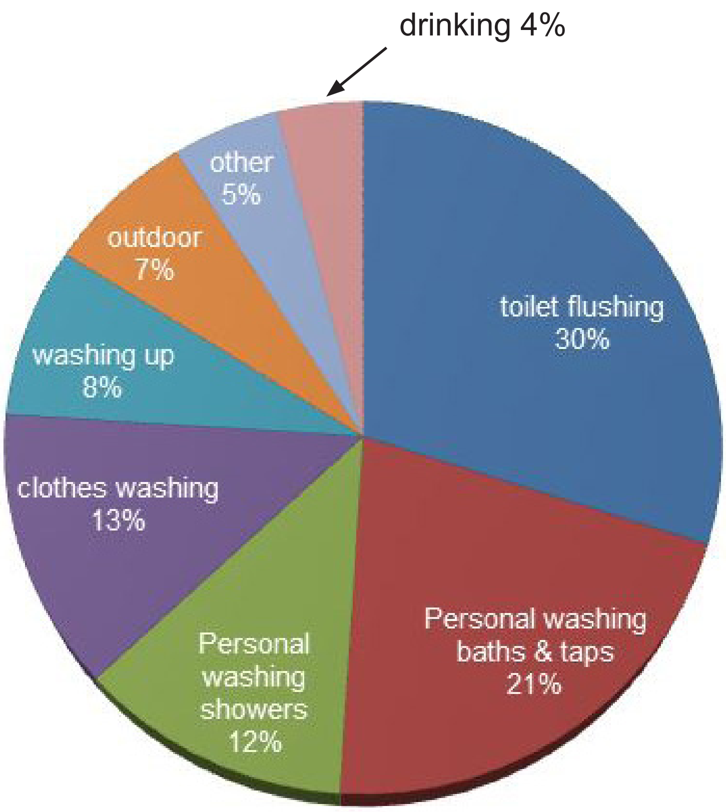
Obtaining clean water (specification 1.3.1)

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 1.3)

Obtaining clean water (specification 1.3.1)

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

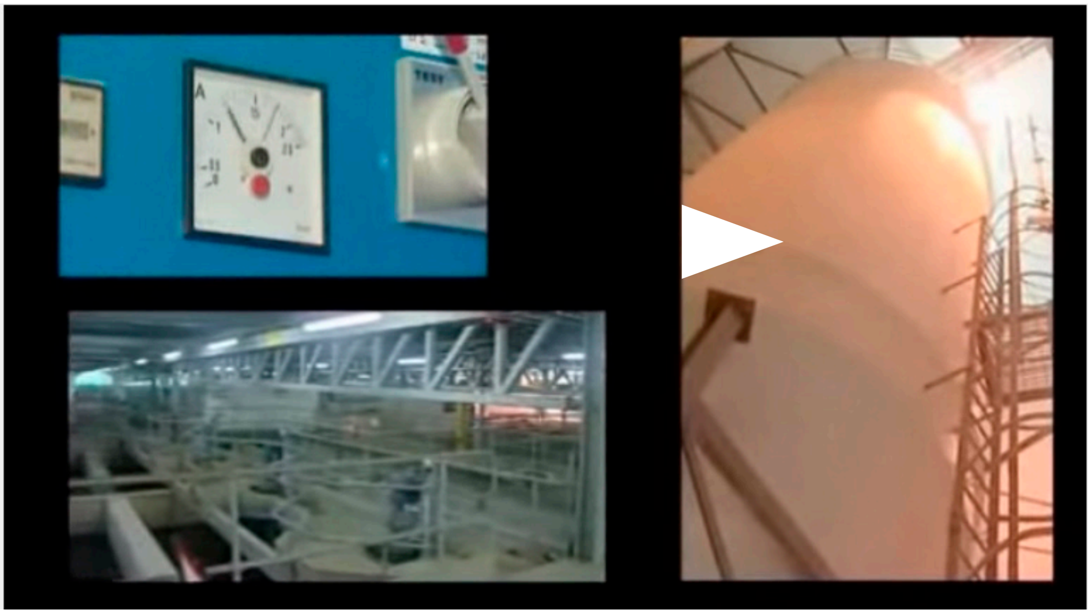
The area served by Welsh Water receives more rain overall than most other parts of the UK. The wettest area is Snowdonia with up to 6 000 mm rainfall a year. Some of that rain runs into rivers and collects in reservoirs where it can be used to provide water for us to drink. 97% of our water in Wales 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 1.3)

Obtaining clean water (specification 1.3.1)

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 1.3)

Obtaining clean water (specification 1.3.1)

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.

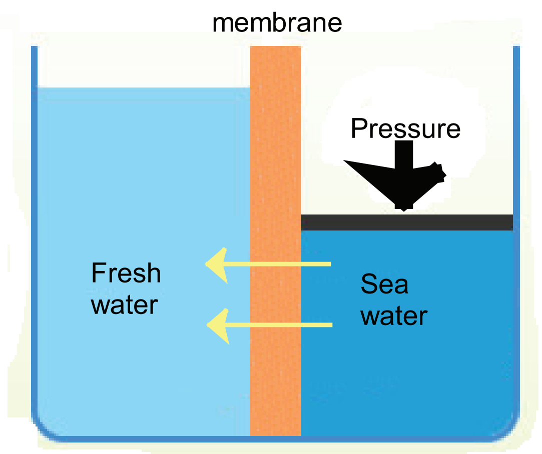
Distillation involves boiling sea water. The water vapour is then cooled and condensed to form pure water - leaving the salt behind.

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.

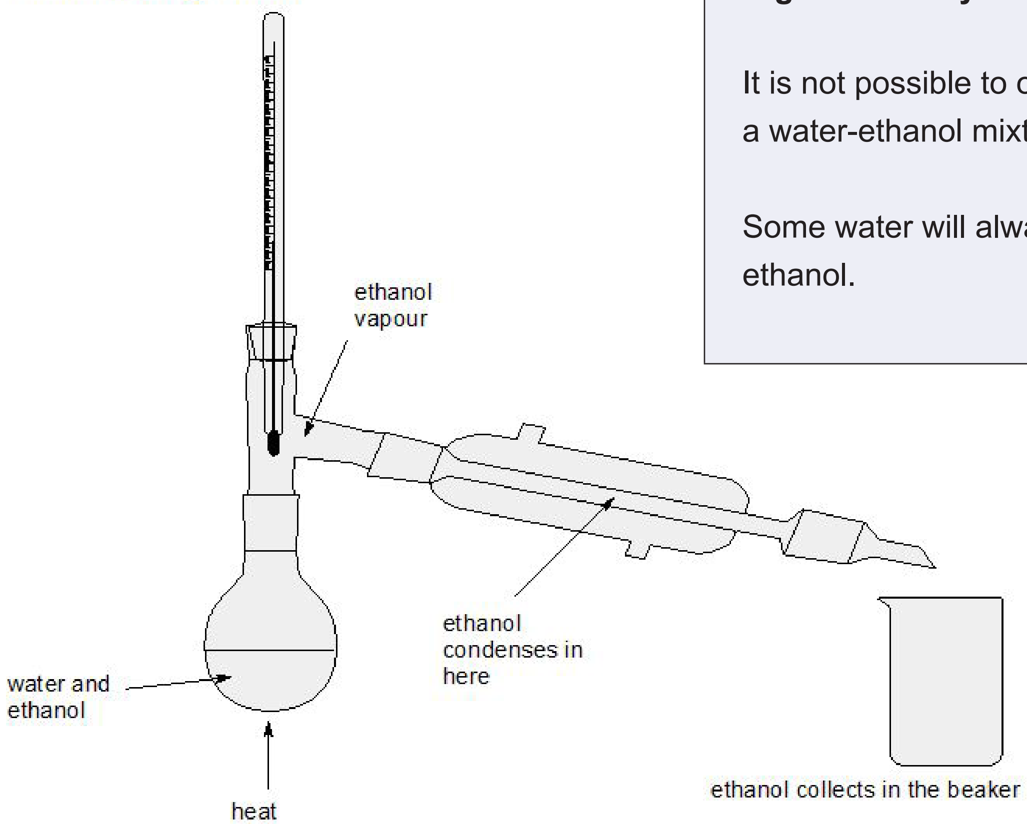
Distillation can also be used to separate two miscible liquids.

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 1.3)

Obtaining clean water (specification 1.3.1)

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 ………………

SOLUBILITY CURVES

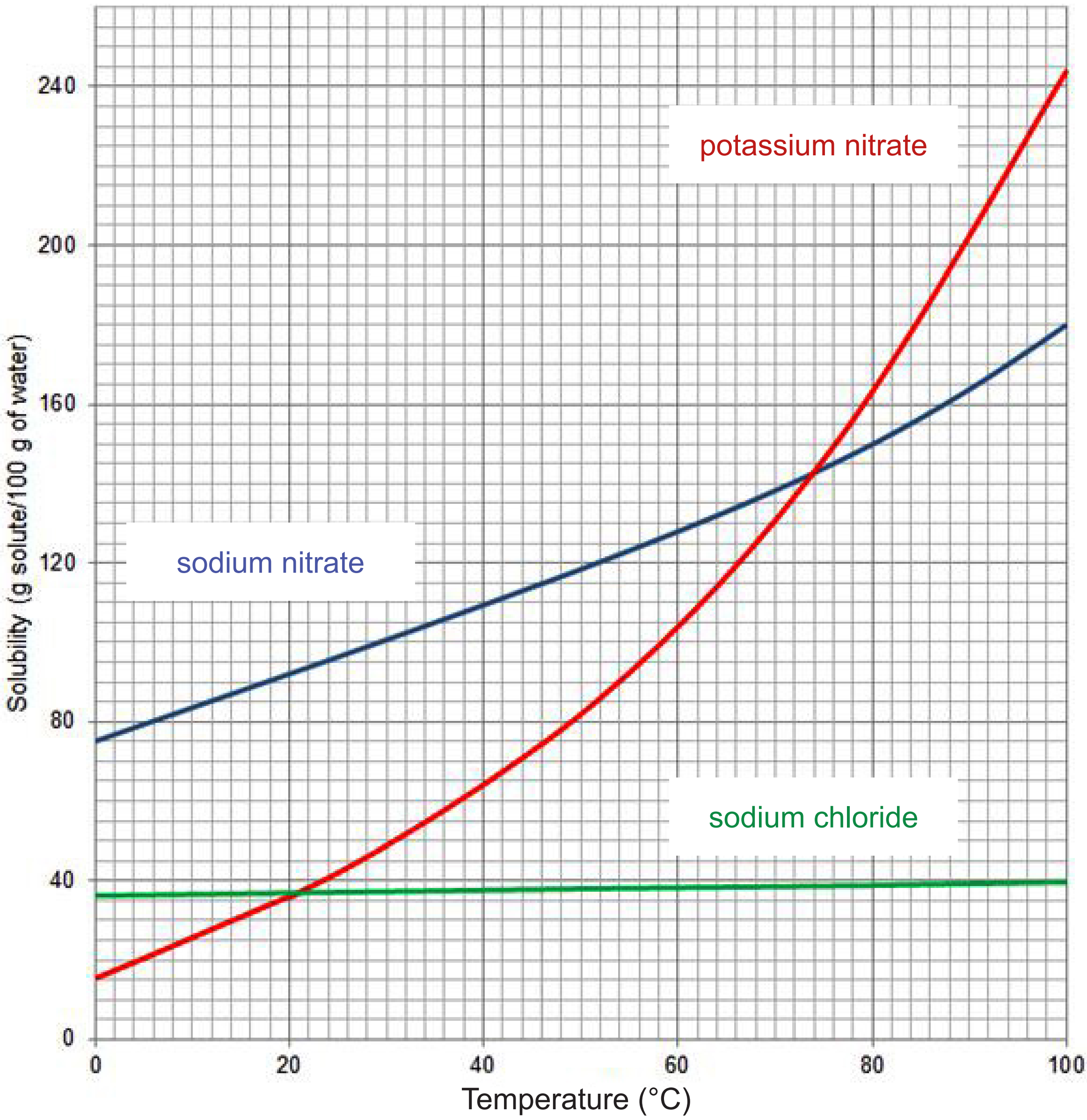
A **solution** is a mixture that results from dissolving a substance in a liquid.

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.

Obtaining resources from our planet (Unit 1.3)

Obtaining clean water (specification 1.3.1)

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

Obtaining resources from our planet (Unit 1.3)

Obtaining clean water (specification 1.3.1)

HARD AND SOFT WATER

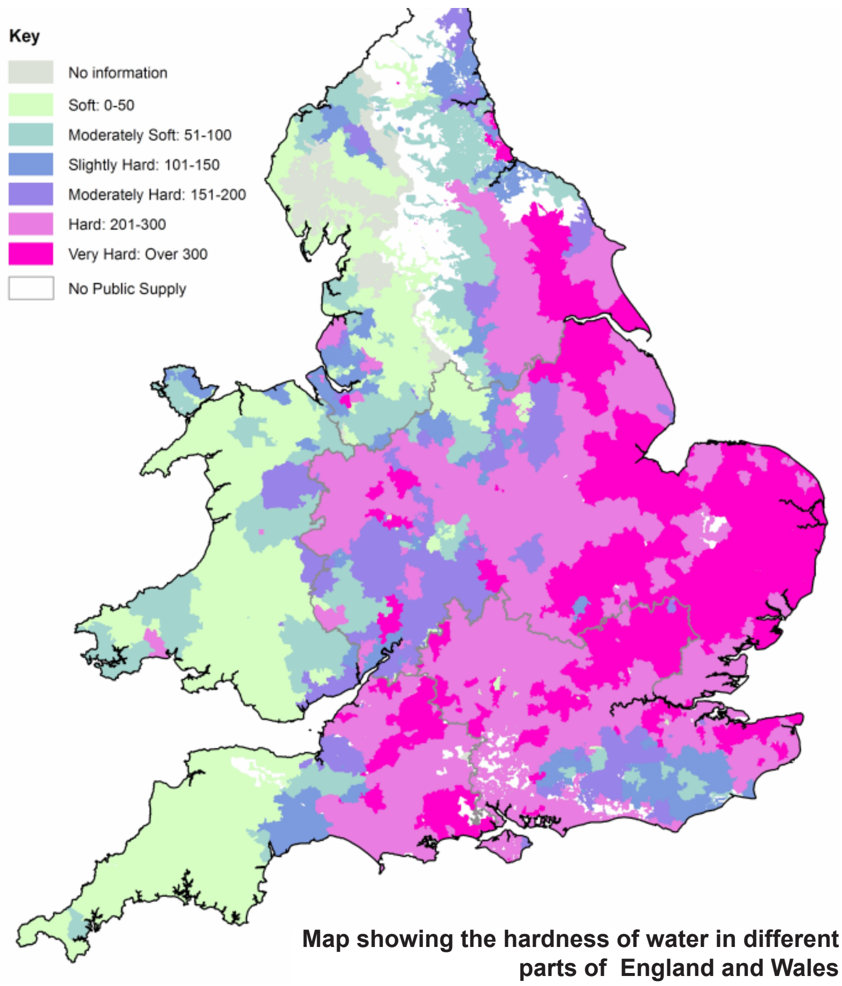
Water is often classed as ‘hard’ or ‘soft’. **Soft water** forms a lather with soap.

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

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 water.

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

$Ca(HCO_3)_2(aq)$ → $CaCO_3(s)$ + $H_2O(l)$ + $CO_2(g)$
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 concentrated solution of sodium chloride.

   The resin beads have sodium ions attached to them.

HIGHER TIER ONLY

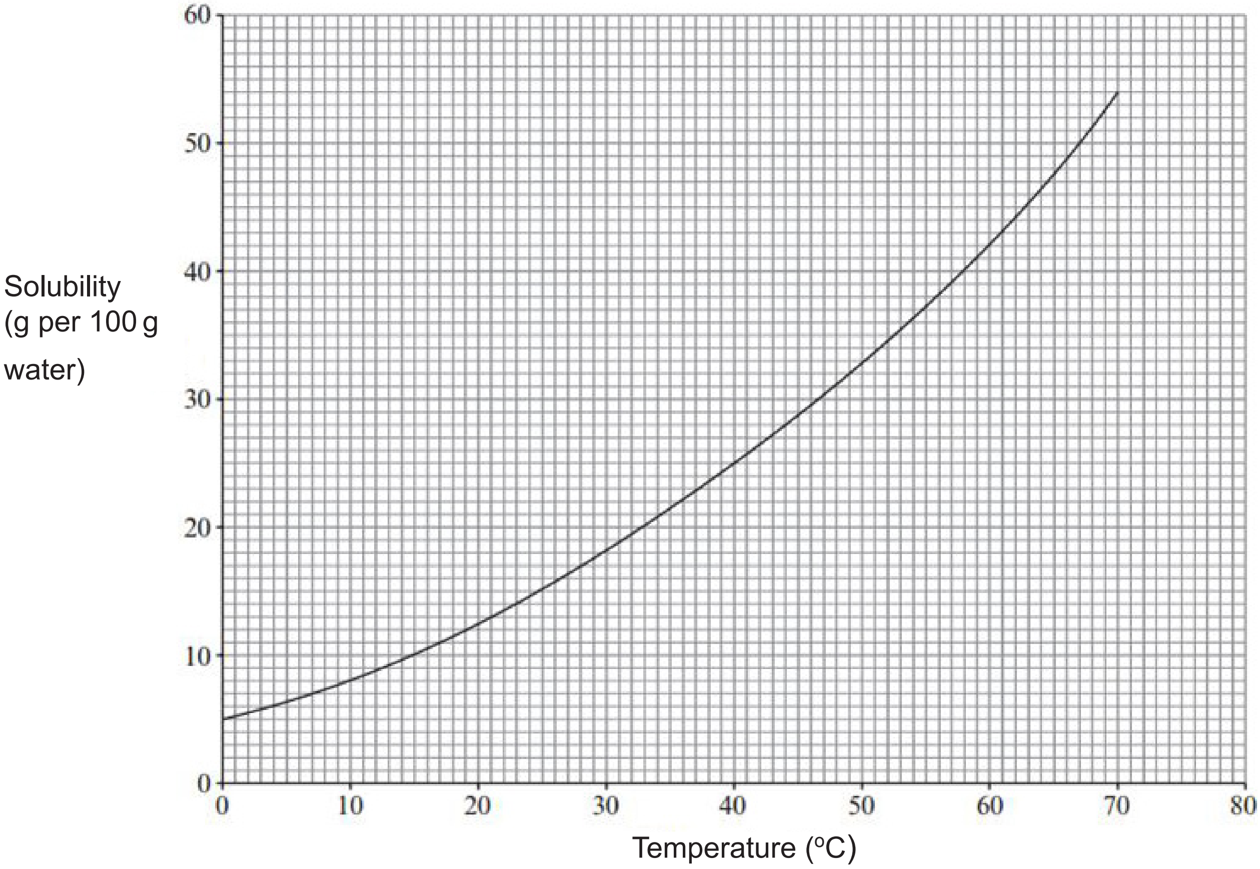
As the hard water passes through the column, the calcium and magnesium ions swap places with the sodium ions.

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 165. **[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 1.3)

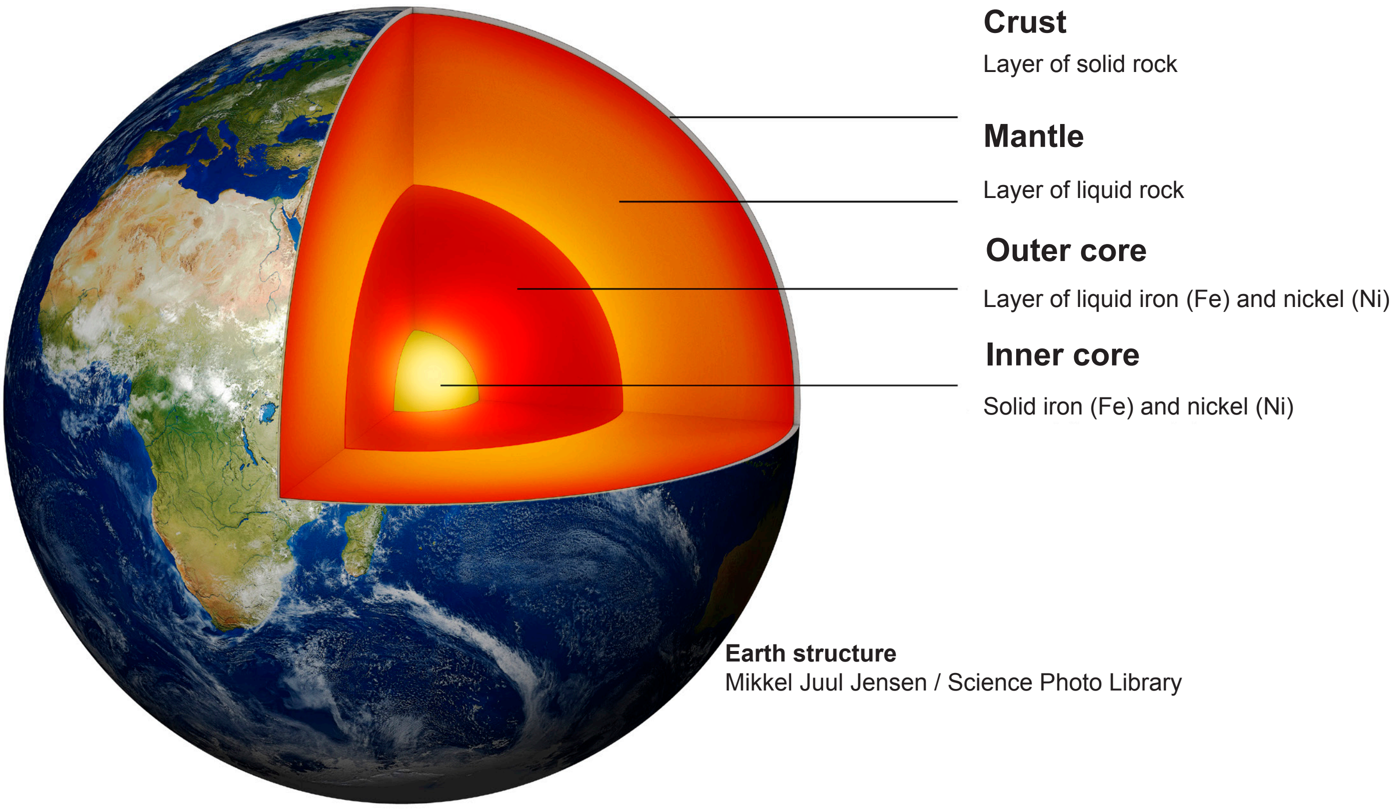
Resources from our planet (specification 1.3.2)

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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.

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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.**

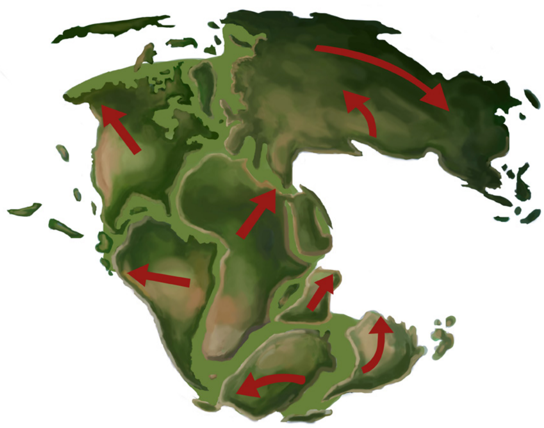
These plates continuously move at the rate of a few centimetres per year in relation to one another.

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.**

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 **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.

Obtaining resources from our planet (Unit 1.3)

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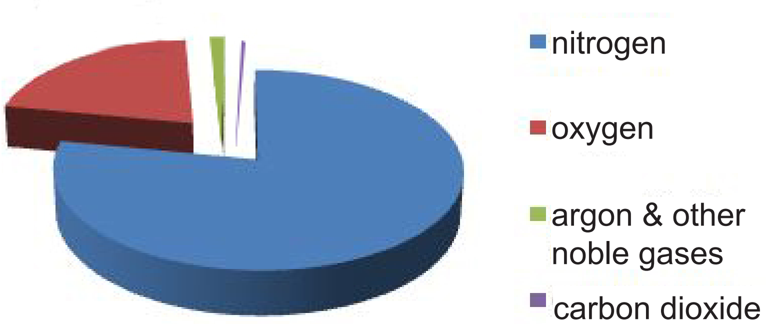
THE EARTH'S ATMOSPHERE

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

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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

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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**).

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

THE PERIODIC TABLE

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

Groups

Periods

Metals

Non-metals

Period	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).

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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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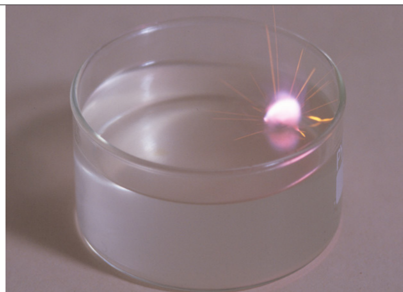
Chemical properties of group 1

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 flame	 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

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Chemical properties of group 7

Element	Reaction with iron
F	Cold iron wool burns in cold fluorine
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

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

TEST YOURSELF

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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 1.3)

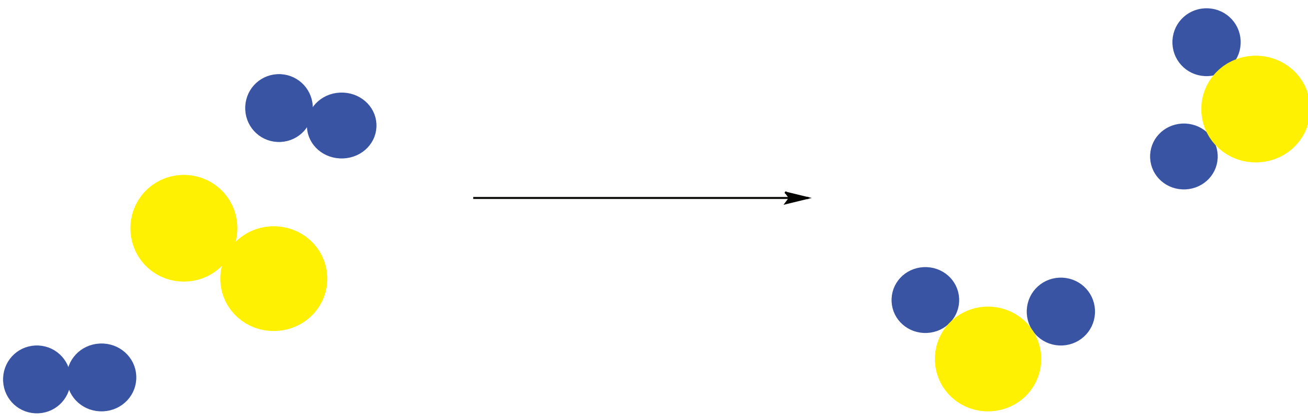
Resources from our planet (specification 1.3.2)

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.

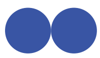
Example

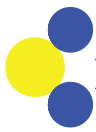


Mixture of hydrogen and oxygen

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
fluorine	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.

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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.

$$Na + Cl_2 \rightarrow NaCl$$

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':

$$Na + Cl_2 \rightarrow 2NaCl$$

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:

$$2Na + Cl_2 \rightarrow 2NaCl$$

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!

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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

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

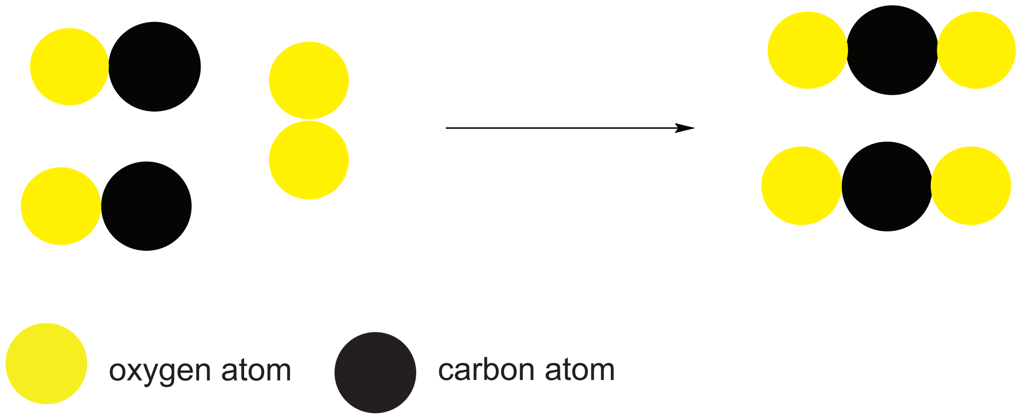
This tells you that sodium was a solid and chlorine was a gas when they reacted.
Sodium chloride was formed as a solid in the reaction.

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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 1.3)

Resources from our planet (specification 1.3.2)

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

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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 1.3)

Resources from our planet (specification 1.3.2)

Benefits

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 resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

Obtaining salt

We can obtain salt via:

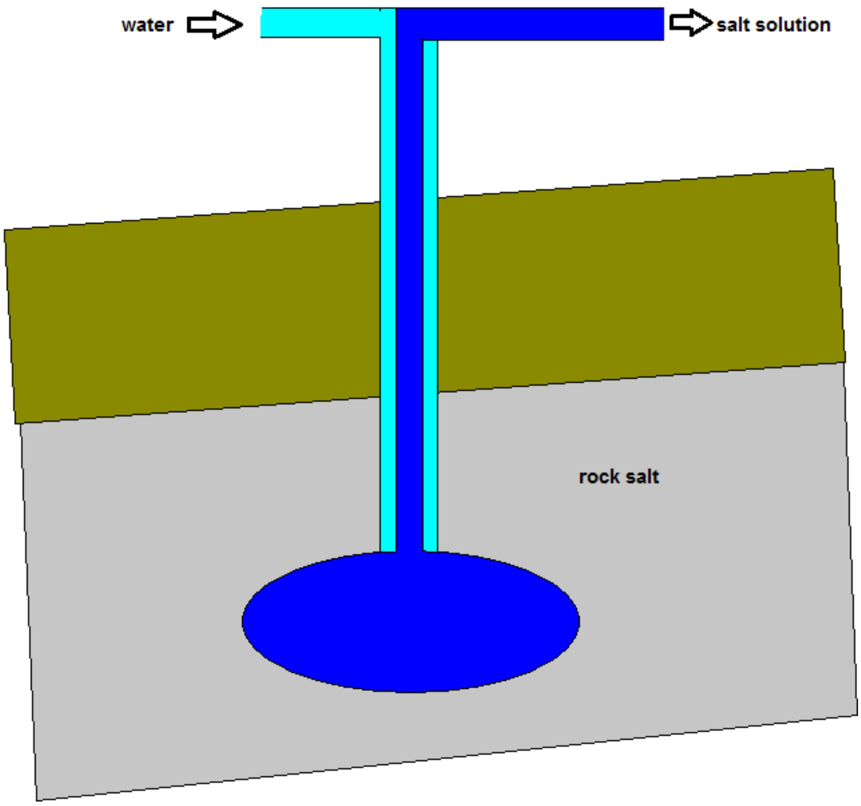
- deep shaft mining
- solution mining.

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

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.

Oil rig
Image Source / Alamy Stock Photo

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 1.3)

Resources from our planet (specification 1.3.2)

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 1.3)

Resources from our planet (specification 1.3.2)

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
Science Photo Library

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.

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

Oil refinery, 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 refinery
Paul Rapson / Science Photo Library

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

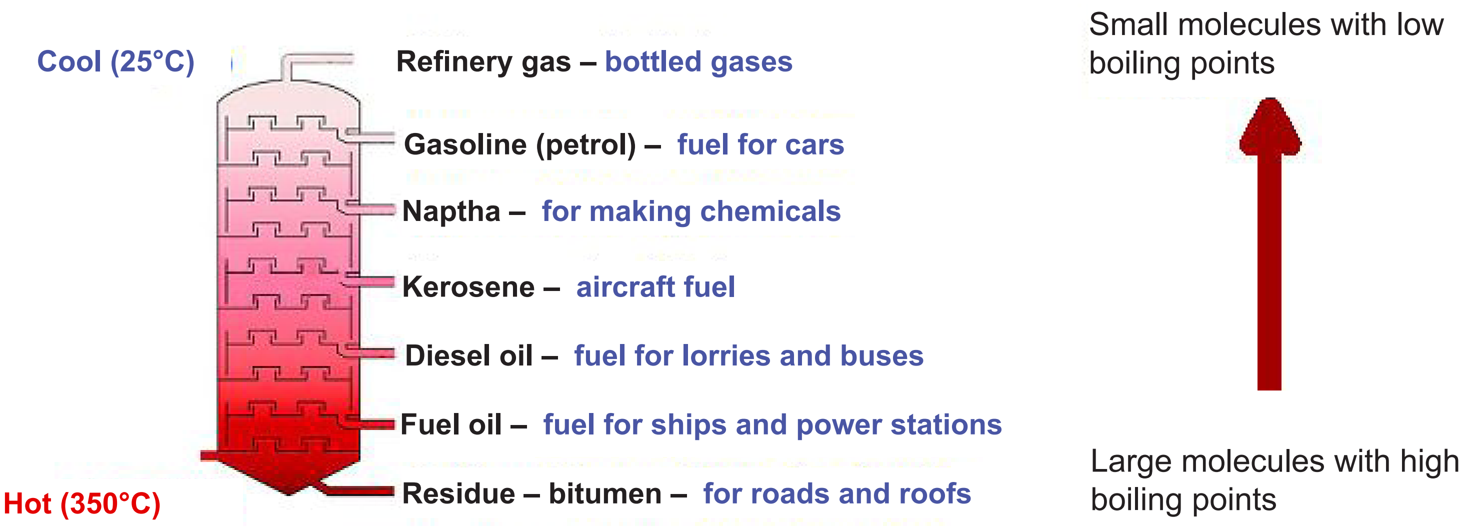
The column is hot at the bottom and cool at the top.

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:



Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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.

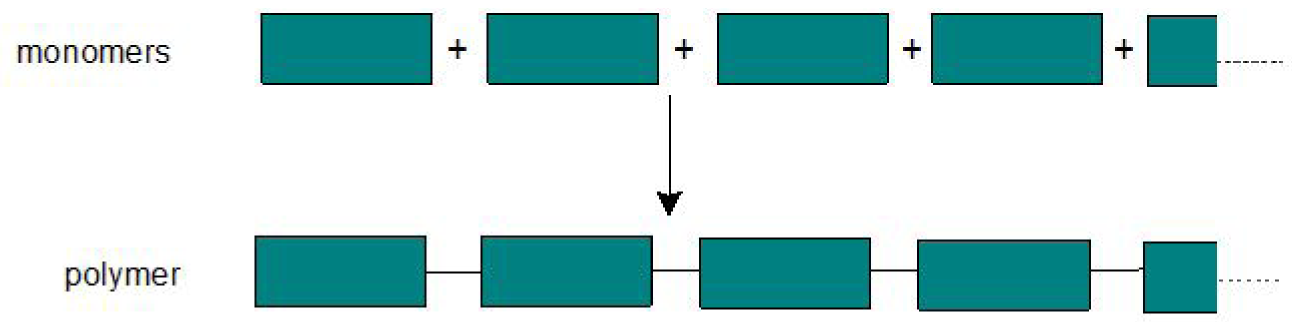
Cracking produces some, small reactive molecules called **monomers** which can be used to make plastics.

Polymerisation

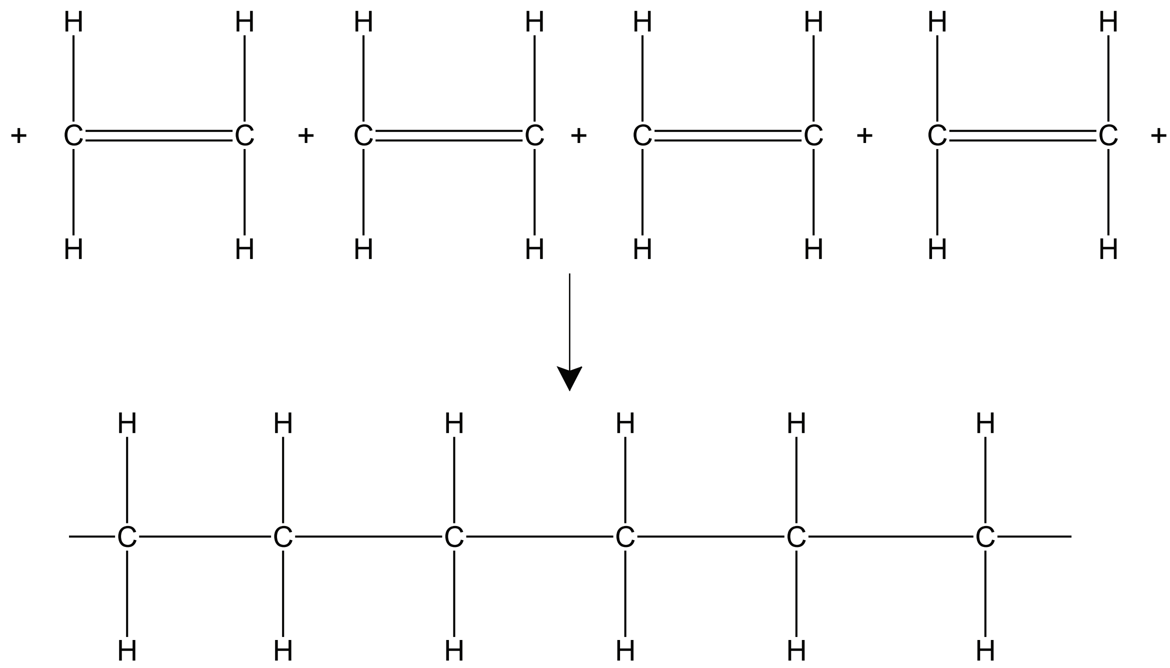
Plastics are made of polymers and are widely used in modern society. Polymer molecules are very long chains of identical molecules.

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:

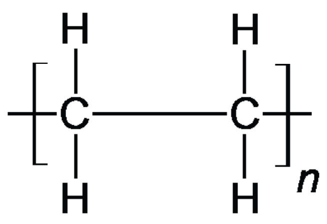


A diagram showing the formation of the polyethene from the monomer ethane is shown below.



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.

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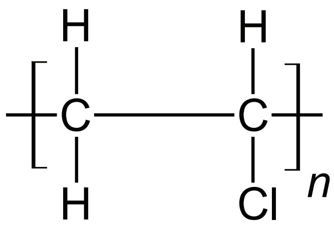
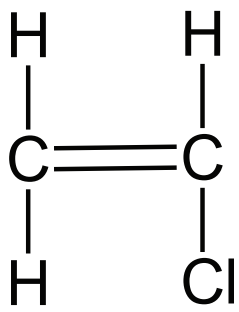
We can make other polymers with different repeat patterns. By changing the atoms in the repeat pattern we change the properties of the polymer.

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

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 1.3)

Resources from our planet (specification 1.3.2)

TEST YOURSELF

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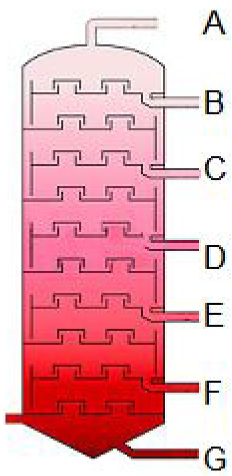
1. Name the process that is used to separate the mixtures in crude oil into fractions.

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 gas
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 life
C contains high concentrations of suspended plastics

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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.**

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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).

Obtaining resources from our planet (Unit 1.3)

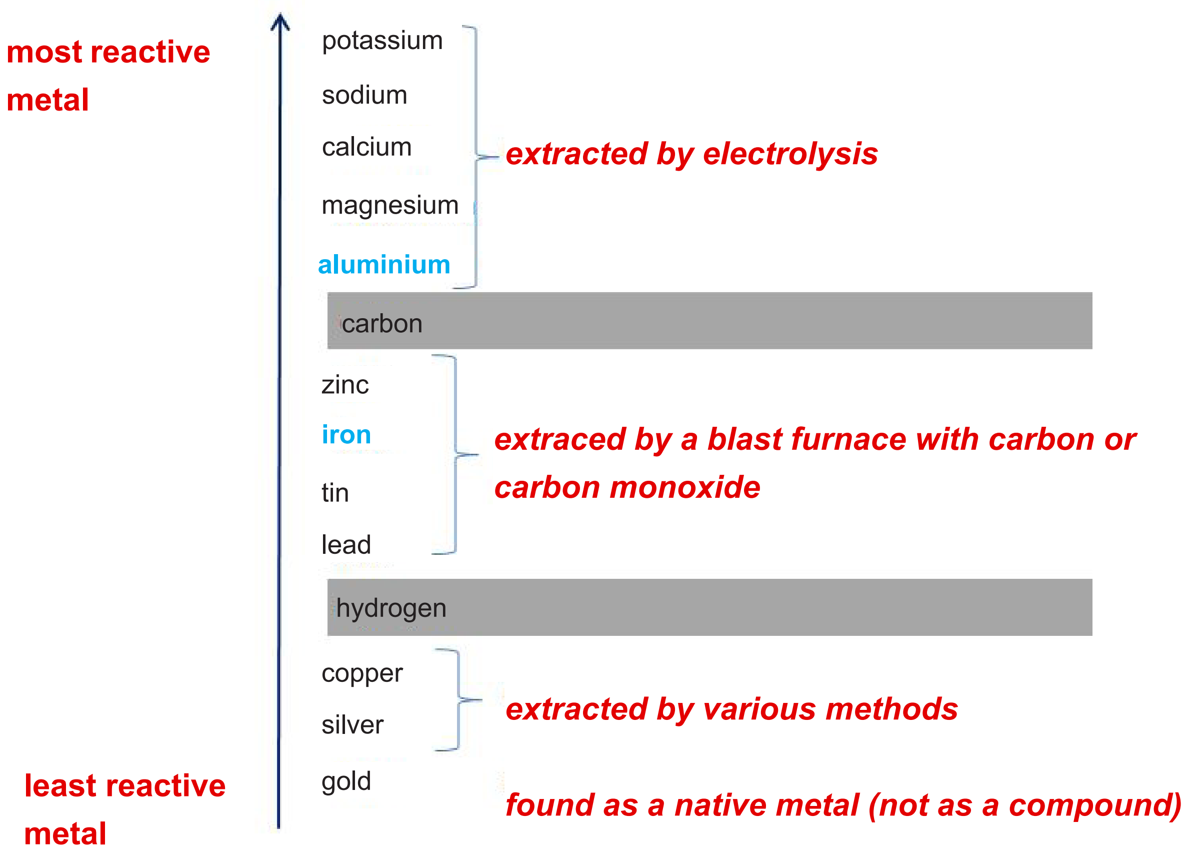
Resources from our planet (specification 1.3.2)

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

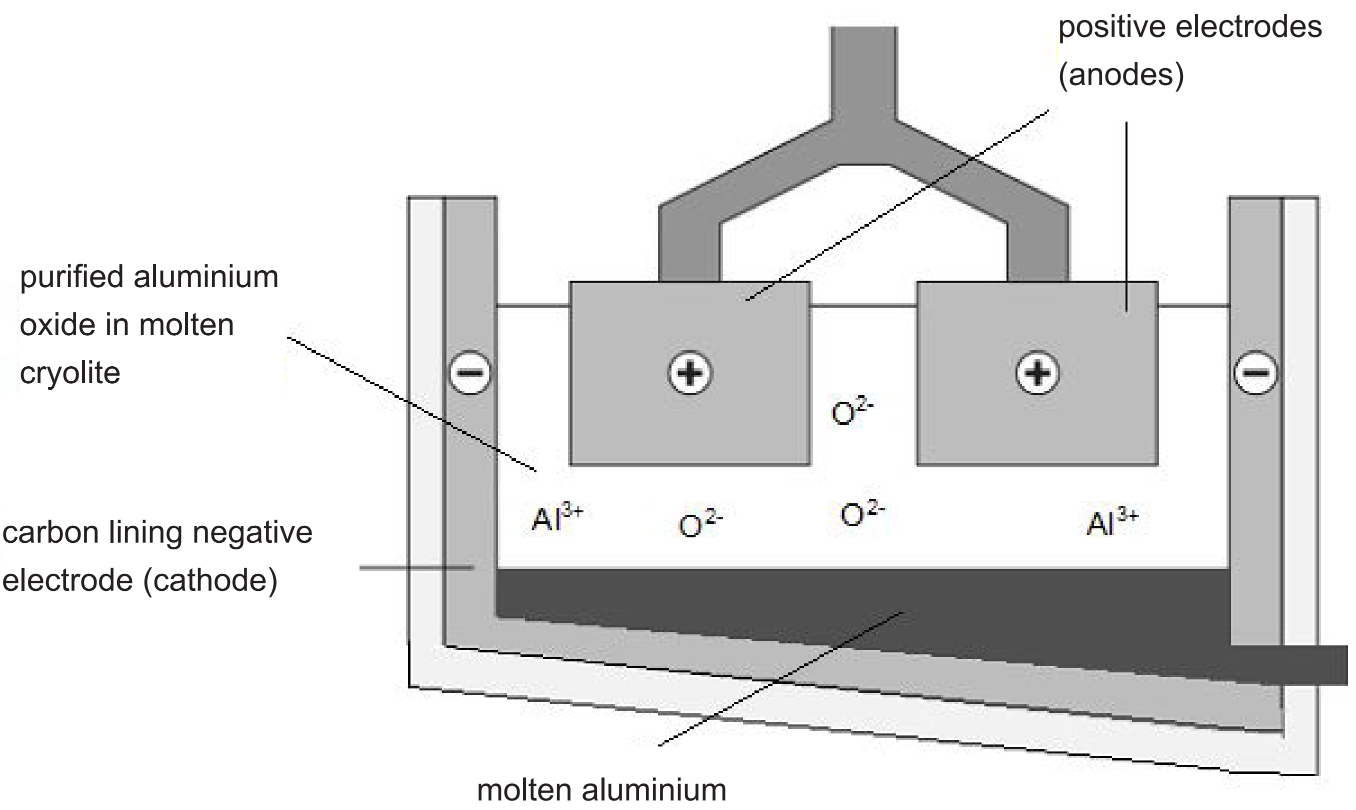
There is more than one way to reduce a metal ore. The method we use depends upon the reactivity of the metal. The more reactive the metal, the harder it is to reduce. Very reactive metals are extracted using electricity, while less reactive metals are extracted by reduction with carbon.

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.

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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.

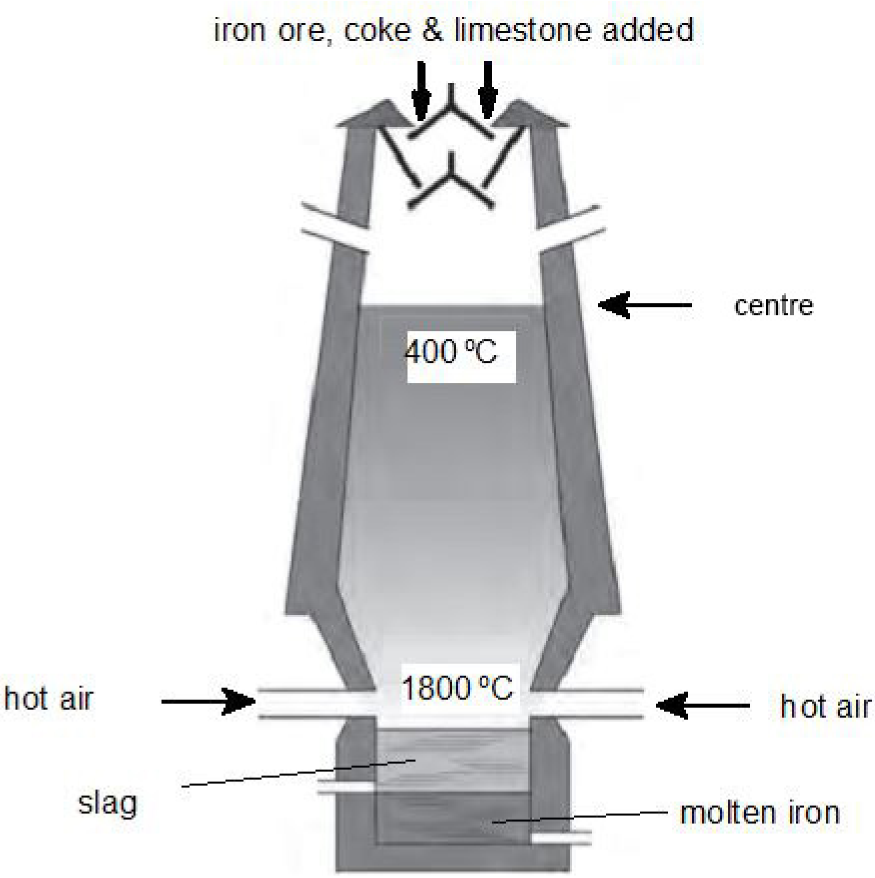
carbon monoxide + iron(III) oxide → carbon dioxide + iron

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

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 ºC
1800 ºC
hot air
hot air
slag
molten iron

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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 different metals ready for recycling since many metals we use are alloys (mixtures of metals).

Obtaining resources from our planet (Unit 1.3)

Resources from our planet (specification 1.3.2)

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

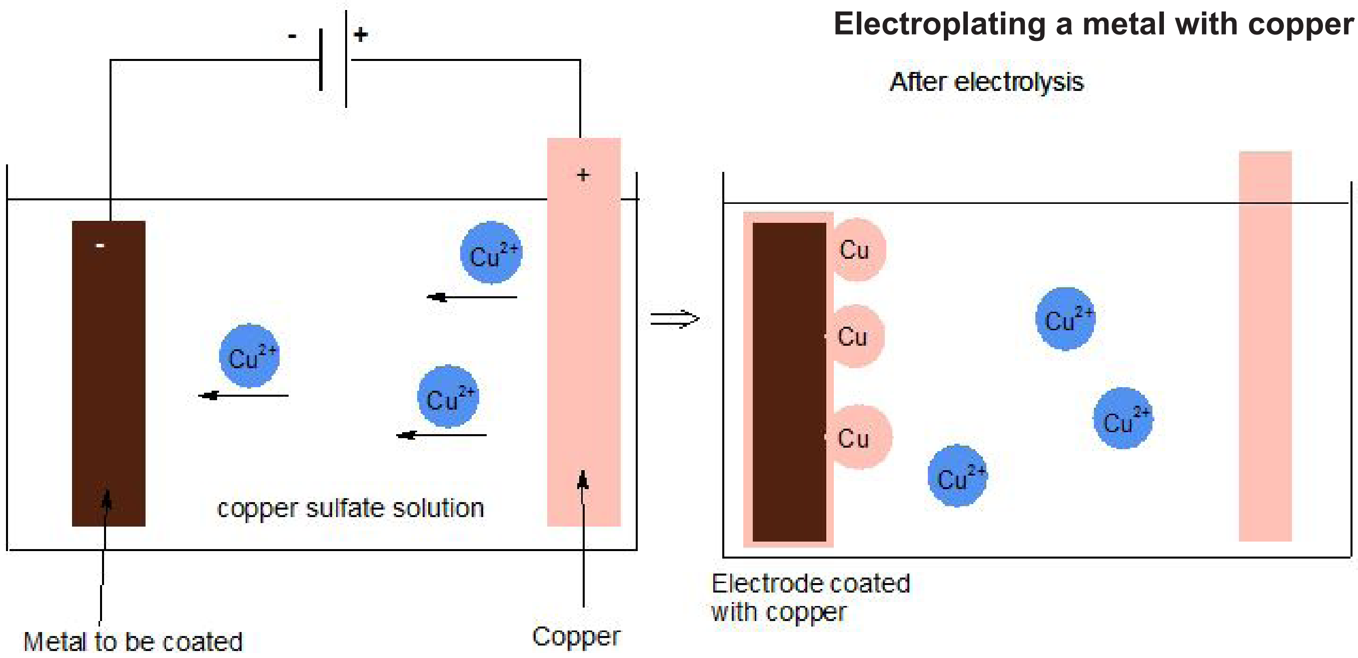
Set up the apparatus as follows:

- 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.

Electroplating a metal with copper



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Resources from our planet (specification 1.3.2)

SOMETHING TO WATCH

Watch a video explaining electrolysis:

https://youtu.be/U9Y8xclePOw

Published on 21 Apr 2012 Category Education Licence Standard YouTube Licence

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 1.3)

Resources from our planet (specification 1.3.2)

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:

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

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

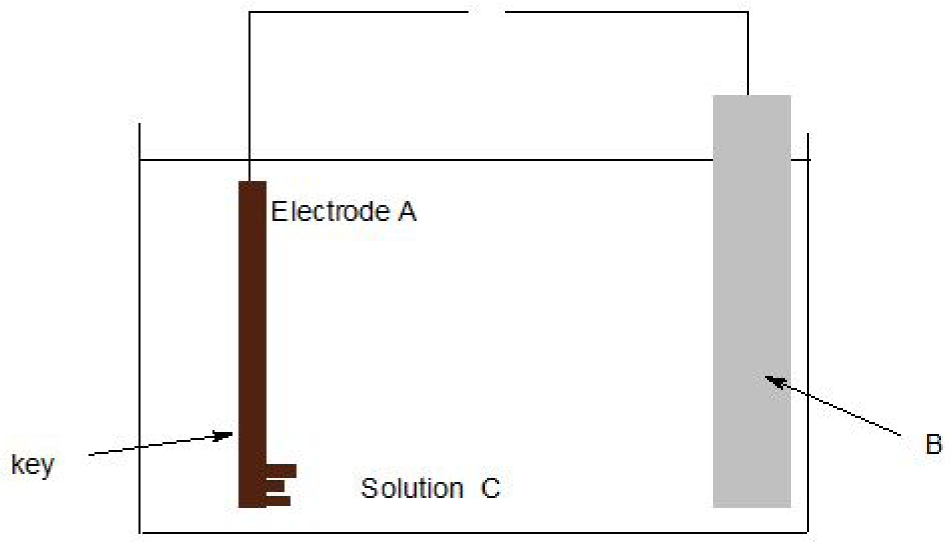
A 1, 1, 2
B 2, 2, 2
C 3, 3, 2

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 (**Al^{+} / 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.



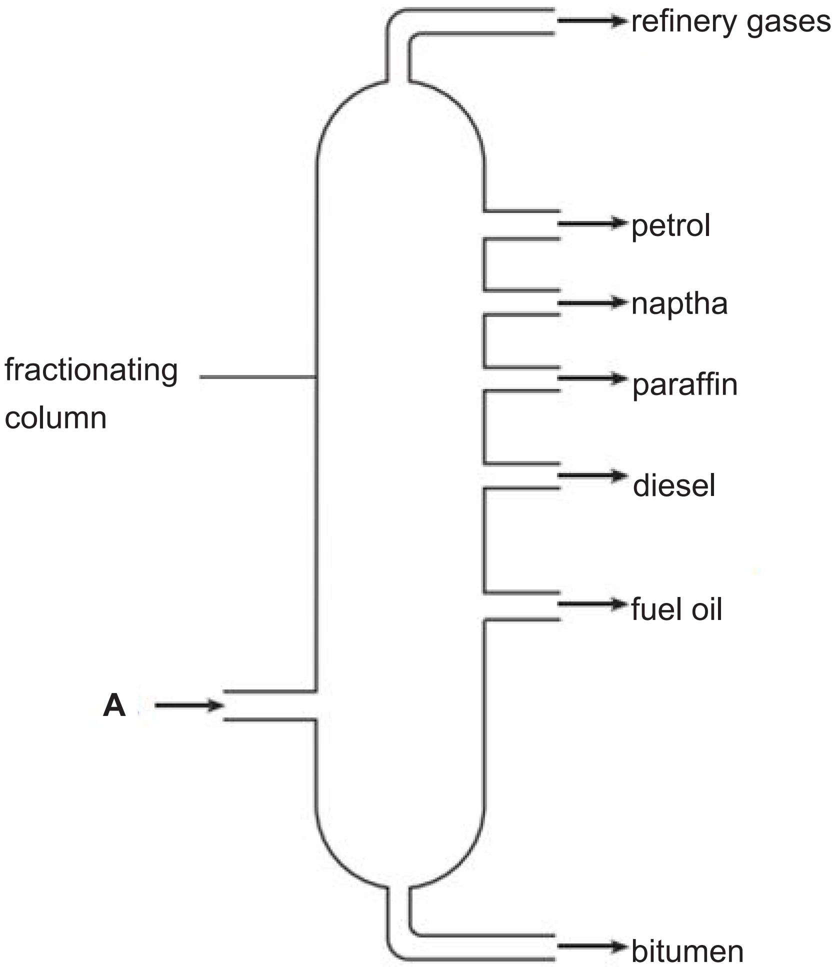
There is a (**positive / negative**) charge on the electrode A.

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]

....

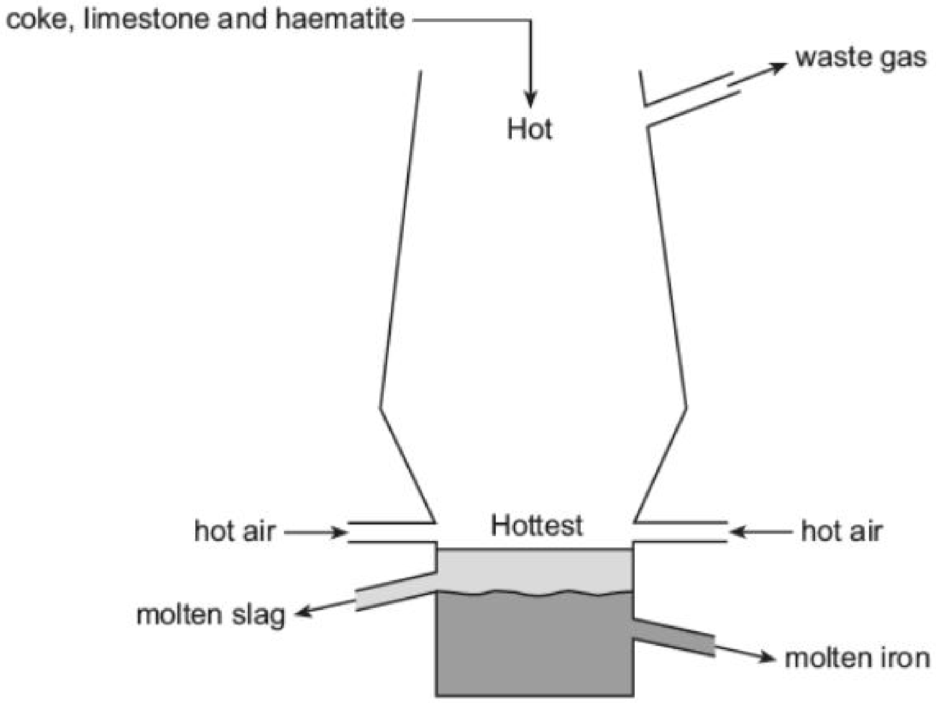
II. in order to collect the fractions as liquids. [1]

....

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

....

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



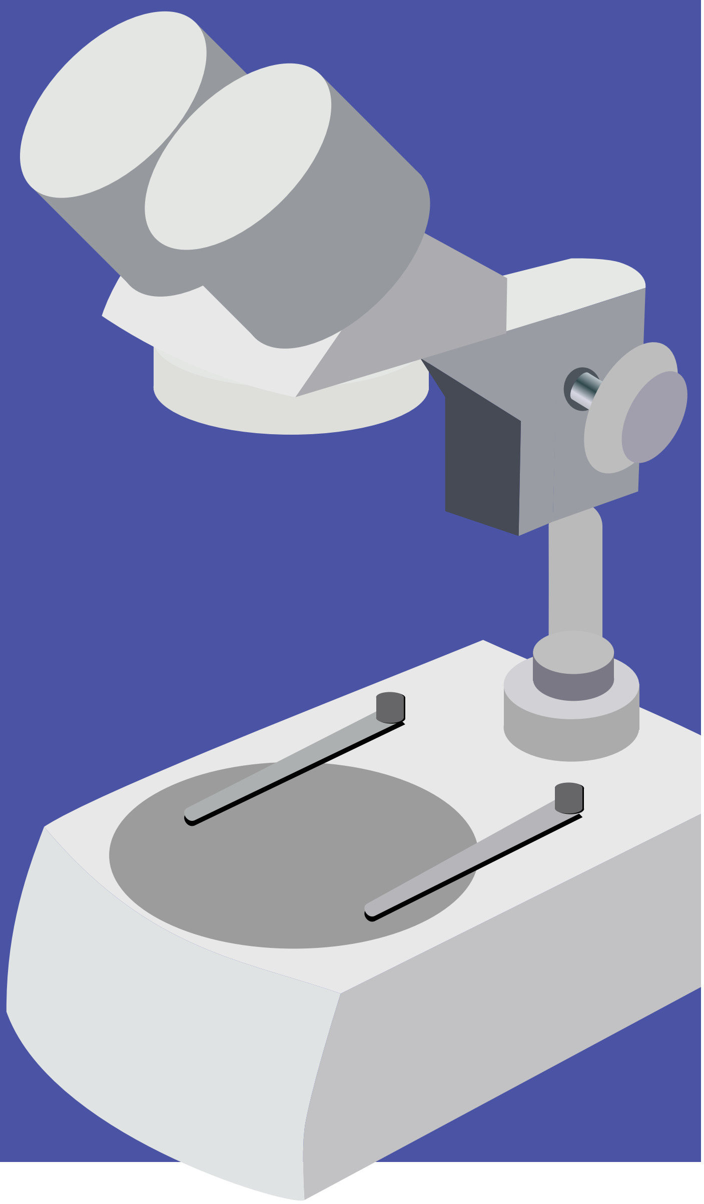
The table shows some information about the raw materials used in the process.

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 1.3)

Producing useful compounds in the laboratory
(specification 1.3.3)



Obtaining resources from our planet (Unit 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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.

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.

Obtaining resources from our planet (Unit 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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** increasingly alkaline →

Obtaining resources from our planet (Unit 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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

Obtaining resources from our planet (Unit 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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	$Mg(NO_3)_2$		

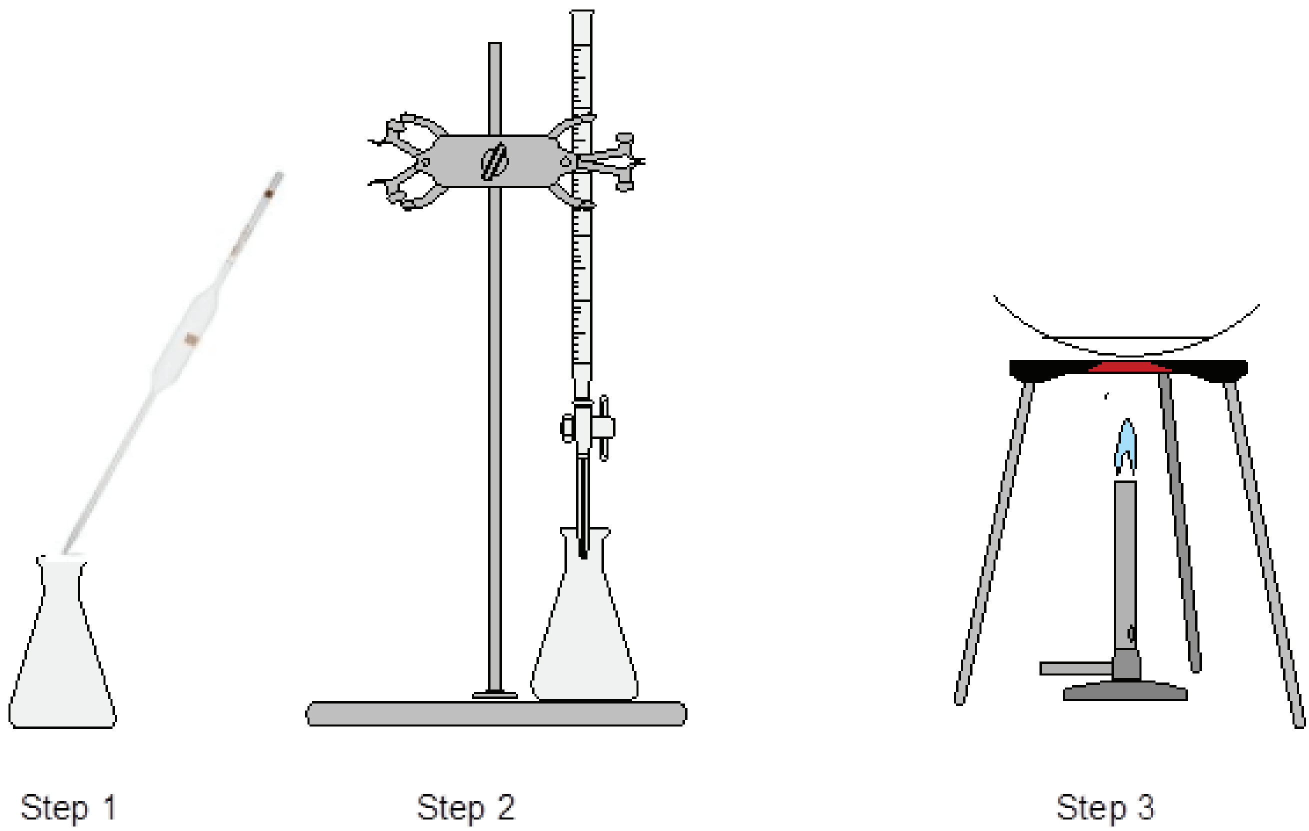
LABORATORY PROCEDURES TO MAKE SALTS

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.

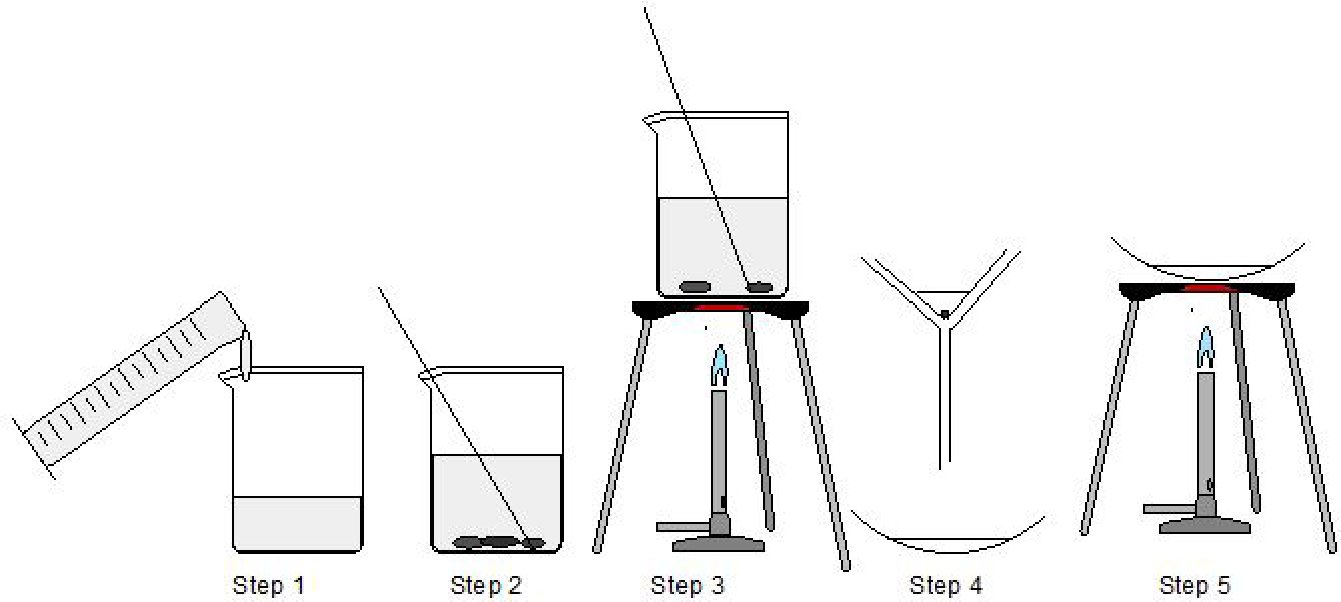
4. The solution is transferred to an evaporating dish and heated to evaporate some of the water causing crystallisation or can be left to very slowly evaporate - which tends to give bigger crystals.

5. The crystals can be collected by filtration and dried.

Obtaining resources from our planet (Unit 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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 1.3)

Producing useful compounds in the laboratory (specification 1.3.3)

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 dioxide
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.

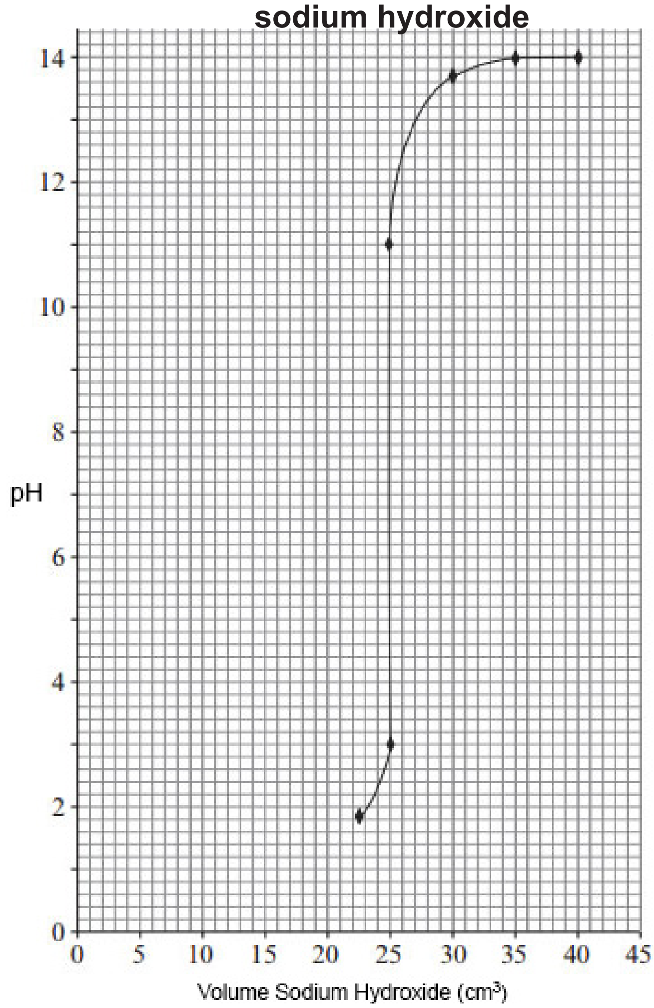
A silver nitrate and sodium carbonate
B silver sulfate and sodium chloride
C silver nitrate and sodium chloride

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]

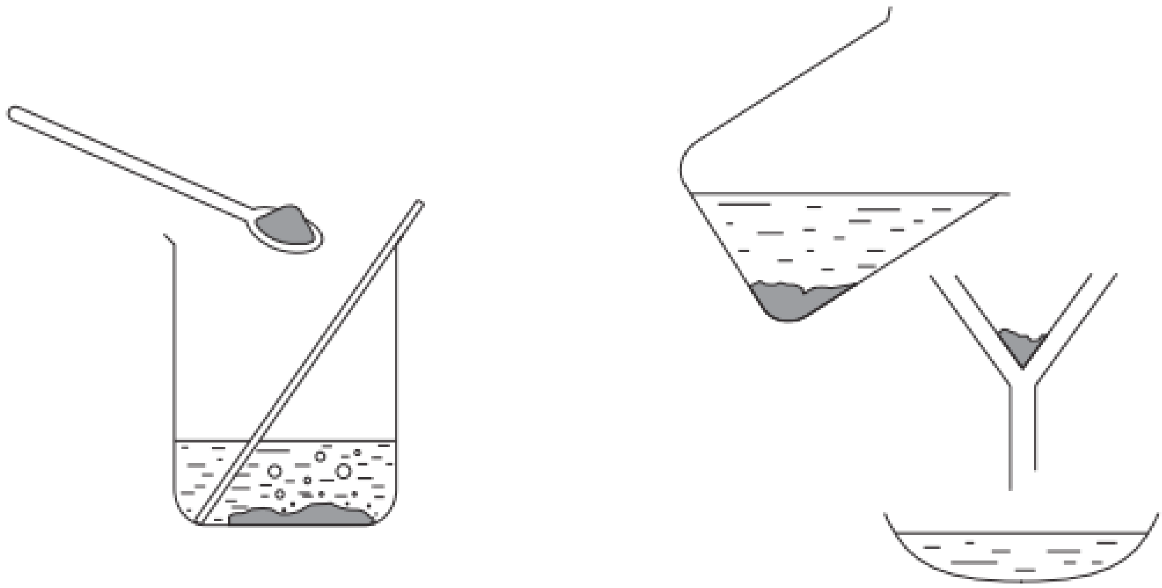
....

....

....

....

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 1.3

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 1.3

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

ANSWERS TO PRACTICE QUESTIONS FOR UNIT 1

The Cell and Respiration

1.	**(a)**		A – nucleus; B – chloroplast; C – cell wall; D – vacuole	**4x1**
2.	**(a)**		Respiration (1), reaction between oxygen and glucose (1), producing carbon dioxide and water (1).	**3**
	(b)		Any three: anaerobic respiration, production of lactic acid, oxygen debt, causes pain/cramp.	**3**

Digestion

1.	**(a)**	**(i)**	Pancreas / small intestine	**1**
		(ii)	small intestine	**1**
		(iii)	mouth	**1**
	(b)	**(i)**	carbohydrase / amylase (spelling must end in –ase)	**1**
		(ii)	glucose NOT simple sugar (can be neutral)	**1**

2. **(a)** at 200°C or at lower temperature (enzyme and protein) molecules are moving slower/ ORA
therefore fewer collisions or description of fewer collisions or fewer reactions/ ORA
fewer protein molecules broken down / digested or fewer amino acids produced / less digestion/ ORA
fewer amino acid molecules move/ go into side B. NOT time taken

(Any 3 from 4)

(b) At 90°C or higher temperature enzyme denatured or destroyed/ ORA **1**

fewer reactions / fewer amino acids produced/ less digestion/ ORA **1**

NOT slower/ rate of reaction decreases.

3. (a)

reagent used	molecule tested for	colour of reagent	colour of plasma after testing	positive result = ✔ negative result = **X**
Benedicts	glucose	***blue***	brick red	✔
Iodine	starch	***brown***	brown	**X**
Biuret	***protein***	***blue***	violet	✔

(b) Starch is too large to pass through the wall of the small intestine **(1)**
so is digested (1)
by an enzyme (1)

3

Higher Tier Only

4. (a) Active transport/ uptake **1**
(b) Oxygen/ O_2 **1**
Glucose **1**
NOT ATP

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**

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