WJEC

GCSE Applied Science

SINGLE AND DOUBLE AWARD

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Specified practical

Investigation of the factors that affect the rate of respiration

Students investigated the effect of glucose on the rate of respiration in yeast, a microscopic fungus. During respiration, bubbles of carbon dioxide are produced.

Procedure

1. 10 cm^3 of yeast suspension were measured into the boiling tube.
2. 10 cm^3 of 2% glucose solution were added.
3. Stirred with a stirring rod.
4. A few drops of oil on the top of the liquid were added using a pipette. It should have formed a layer over the surface.
5. The apparatus was assembled as shown in Figure 1.5.
6. The stopwatch was started when the first bubble appeared, and then the total number of bubbles produced in 2 minutes were counted.
7. Steps 1–6 were repeated with 4, 6, 8 and 10% glucose solution.
8. A line graph of concentration of glucose against number of bubbles per 2 minutes was plotted.

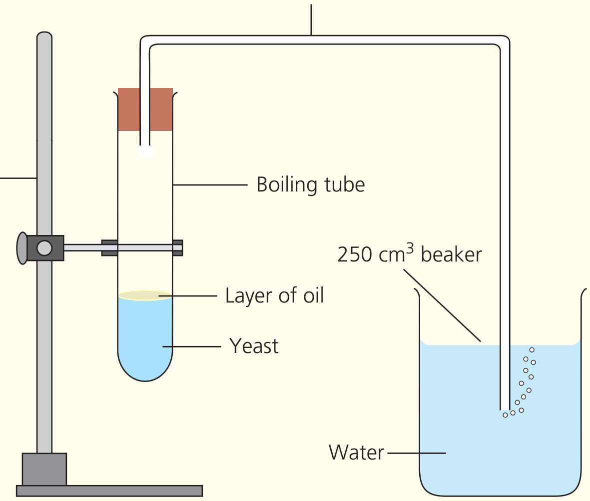


Figure 1.5 Experimental setup

Analysing the results

1. What are your conclusions about the effect of temperature on the rate of respiration?
2. Explain why this method is a fair test.
3. Explain how you would vary this method to test for the effect of temperature on respiration, instead of glucose concentration.

Chapter summary

- Animal and plant cells have the following parts: cell membrane, cytoplasm, nucleus; in addition, plants cells have a cell wall, vacuole and sometimes chloroplasts.
- Cells differentiate in multicellular organisms to become specialised cells, adapted for specific functions.
- Tissues are groups of similar cells with a similar function; organs may comprise several tissues performing specific functions.
- Diffusion is the passive movement of substances down a concentration gradient.
- The cell membrane forms a selectively permeable barrier, allowing only certain substances to pass through by diffusion, most importantly oxygen and carbon dioxide.
- Visking tubing can be used as a model of a cell membrane.
- H Active transport is an active process by which substances can enter cells against a concentration gradient.
- Aerobic respiration is a series of enzyme-controlled reactions that occur in cells when oxygen is available.
- Aerobic respiration uses glucose and oxygen to release energy, and produces carbon dioxide and water.
- Anaerobic respiration occurs when oxygen is not available. In animals, glucose is broken down into lactic acid/lactate.
- During strenuous exercise, anaerobic respiration in muscles builds up an oxygen debt, which is repaid after the exercise by breathing faster and deeper than normal.
- Anaerobic respiration is less efficient than aerobic respiration.

2 Obtaining the materials for respiration

The respiratory system

The function of the respiratory system is to extract oxygen from the air and move it into the blood, so it can travel to all cells in the body. The respiratory system also removes carbon dioxide, which is a waste product of respiration.

Structure of the respiratory system

The respiratory system of a human is shown in Figure 2.1.

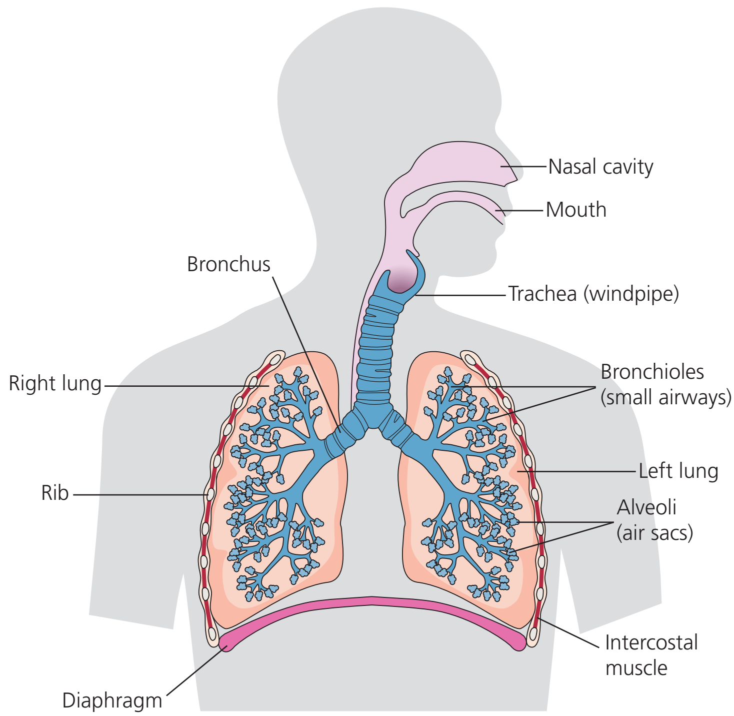


Figure 2.1 The human respiratory system

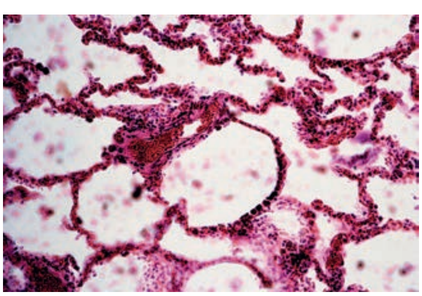


Figure 2.2 Microscopic section of lung tissue. The lungs are sponge-like and mostly composed of air

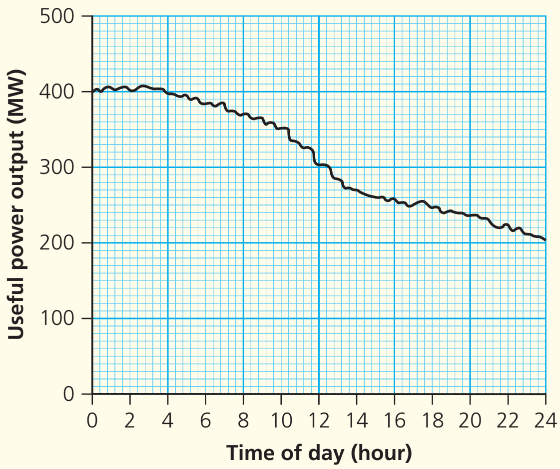
Air travels into the body via the nose and mouth. It enters the lungs through the **trachea**, which splits into two **bronchi** (singular: bronchus), one going to each lung. Each bronchus splits into a number of smaller tubes, the **bronchioles**, which eventually end in a cluster of **alveoli** (singular: alveolus) (Figure 2.2). Gases are exchanged only in the alveoli – carbon dioxide goes out of the blood, and oxygen goes in. The respiratory system is protected by the ribs. The lungs are inflated and deflated using the **intercostal muscles** and the **diaphragm**.

How air is breathed in and out

When the lungs expand, they suck air in; when they contract, they push air out again. Although they are elastic (springy), the

Practice exam questions

1 The graph shows how the combined electrical power usefully transferred by all the wind farms in North Wales changed on 2nd July.



a) Describe how the strength of the wind changed throughout the day. [1]

b) i) Use the graph to determine the combined electrical power usefully transferred at 12.00 hours. [1]

ii) The total power supplied at 12.00 hours to the wind farms was 600 MW.

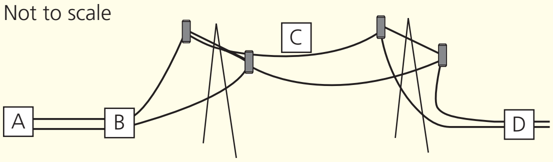
Use the equation:

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

to calculate the combined efficiency of all the wind farms in North Wales. [2]

2

Not to scale



a) A section of the National Grid is shown. Box A represents a solar power farm.

Use a word from the box below to copy and complete the sentences that follow. Each word may be used once, more than once or not at all.

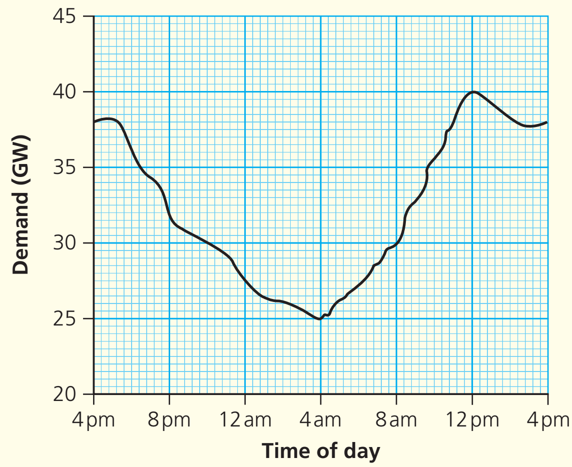
power	generator	pylon	transformer	current

i) At B, the voltage is increased using a … . [1]

ii) Energy losses at C are minimised because the … is reduced. [1]

iii) At D, a … is used to decrease the voltage. [1]

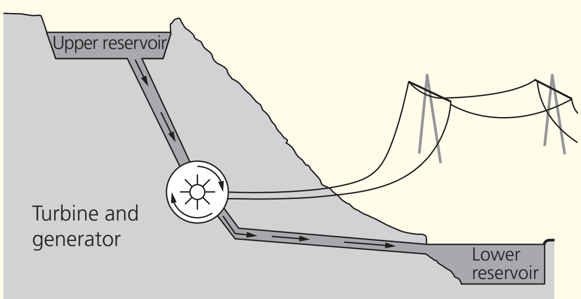
b) The demand for electricity on Anglesey during one day in June, is shown.



i) Use the graph to determine the maximum demand. [1]

ii) Between 4 am and 12 pm, the demand for electricity increased. Use the graph to determine this increase. [1]

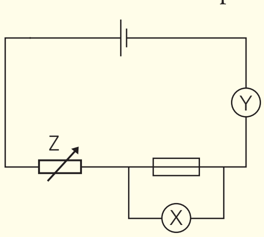
c) A schematic diagram of Dinorwig pumped hydroelectric power station is shown. At night, water is pumped from the lower to the upper reservoir, using electricity from the National Grid.



i) Suggest a reason why the water is pumped up to the top reservoir at night. [1]

ii) Dinorwig was used to supply Anglesey with electricity between 11 am and 12 pm. Suggest a reason why. [1]

3 The circuit diagram may be used to find the resistance of a fuse used as part of a model electric train set.



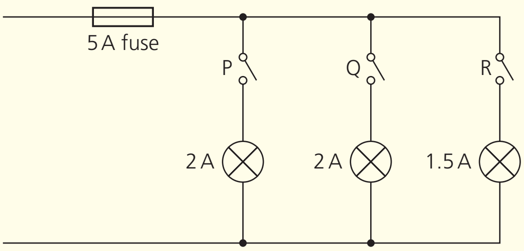
a) Identify components X, Y and Z. [3]

b) Use the equation:

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

to calculate the resistance of the fuse if its voltage is 6 V and the current is 1.5 A. [2]

c) The fuse is put into the train track lighting circuit shown below.



i) Calculate the total current drawn from the supply when switches P, Q and R are pressed ON. [2]

ii) State what will happen to the fuse and the lamps when these three switches are pressed ON. [2]

4 A homeowner has a maximum of £3000 available to spend on improving home insulation. Information on each type of insulation is shown in the table.

Part of house	Insulated or not	Energy lost per second (W)	Cost of insulation (£)	Payback time (years)	Expected annual saving (£ per year)
Loft	None	4500			
	Thick fibre glass blanket	1200	600	X	200
Cavity wall	None	3400			
	Expanded foam	1400	1800	10	180
Doors	Wood	1000			
	uPVC plastic	800	1500	50	Y
Windows	Single glazing	1800			
	Double glazing	1400	2400	60	40

a) Use the equations below:

$$\text{payback time (years)} = \frac{\text{cost of insulation (£)}}{\text{annual savings (£ per year)}}$$

$$\text{annual savings (£ per year)} = \frac{\text{cost of insulation (£)}}{\text{payback time (years)}}$$

to calculate the missing values X and Y. [2]

b) Use information from the table to advise the homeowner on how best to spend a maximum of £3000 on insulation. [6]

H

c) Use the table to calculate the energy loss per second from the house when it is:

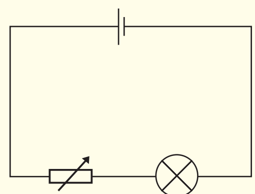
i) Un-insulated [1]

ii) Fully insulated [1]

iii) Use your values from c) i) and ii) to determine the percentage decrease in energy loss from the un-insulated house to the fully insulated house. [2]

5 David investigated how the current through a 12 V filament lamp varied with the voltage across it, from 0 and 12 V.

a) Part of the circuit that David used is shown in the diagram. Copy the diagram and add a voltmeter and an ammeter to the circuit. [2]



b) Describe the method that the student could use to take a range of results. [3]

c) The student obtained the following readings of current against voltage for the lamp.

Voltage (V)	Current (A)
0.0	0.0
0.5	0.8
2.0	1.6
4.0	2.1
6.0	2.4
8.0	2.6
10.0	2.8
12.0	2.9

i) Plot the data on a grid and draw a suitable line of best fit. [3]

ii) Describe the pattern in the data shown on the graph. [2]

d) The student is told that the standard operating voltage of the lamp is 12 V. Use the equation:

$$\text{power} = \text{voltage} \times \text{current}$$

to calculate the power of the lamp at 12 V. [2]

e) A similar lamp has a resistance of 4.8 Ω when the current flowing through it is 3.0 A. Use the equation:

$$\text{power} = \text{current}^2 \times \text{resistance}$$

to calculate the power of this lamp at a current of 3.0 A. [2]

f) The student repeated this experiment with a fixed resistor. The current was 1.5 A when the voltage across it was 8 V. Add a line to your graph to show how current varies with voltage for the fixed resistor. [2]

Figure 11.3 This is *Oniscus asellus* – also known as a woodlouse, granny grey and a monkey pea, depending on where you come from! Use of these 'local' names could cause confusion, so scientists always use the scientific name

All species have a scientific name and some also have a 'common' name. The scientific name, which always consists of two words, is used by scientists throughout the world. This means that everyone in the scientific community knows which organism is being referred to. Common names vary in different languages (and even in different regions of the same country), so using them could cause confusion. The woodlouse (Figure 11.3), for example, has many different names in different parts of the UK, including monkey pea (Kent), cheeselog (Berkshire), slater (Scotland), granny grey (South Wales) and parson's pig (Isle of Man)! What is more, all of these names are used for all types of woodlouse, but there are 35 different species in the UK.

The system of using two words in a scientific name (the binomial system) was developed by the Swedish botanist, Carl Linnaeus, in the 18th century. The first name is the name of the organism's genus (a group of closely related species) and the second name indicates the species. For example, the big cats all have the same first name, Panthera, but different second names. The lion is *Panthera leo*, the tiger is *Panthera tigris* and the panther is *Panthera pardus*.

The classification of organisms is not just done using external features. Internal anatomy is also important, and genetic sequencing can also be used to group organisms.

Genetic sequencing

Scientists can analyse an organism's **DNA** and discover which genes are present and their position on the **chromosomes**. The more similar the genetic sequences are in two organisms, the more closely related they are. This has been used to confirm the classification of some species, and also to show errors and reclassify others. For example, in 2016, giraffes, which were previously thought all to belong to the same species, were reclassified and divided into four different species.

Key term

DNA Deoxyribonucleic acid – the chemical from which genes are made and which controls the production of proteins in cells.

Chromosome Thread-like structure made of DNA, found in the nucleus of cells.

Test yourself

4 Why do scientists give organisms scientific names?

5 Four species of frogs have these scientific names:

a) *Rana temporaria* b) *Pelodytes punctatus*

c) *Hyla arboea* d) *Rana iberica*

Which of these species are most closely related? Explain your answer.

6 What is gene sequencing used for in classification?

Evolution and natural selection

Variation

Over long periods of time, animal and plant populations change in ways that make them better adapted to their environment. This gradual change is called evolution. If the environment changes significantly, new adaptations may evolve for the new conditions.

Figure 11.4 Identical twins have identical genes but there are still some differences between them

Evolution can only happen because populations of living things show variation – the individuals in the population are not identical. The genes of an organism control its characteristics and different sets of genes naturally result in variation; because they are caused by genes, these types of variation can be inherited. These can be regarded as naturally occurring variations.

In humans, the only people with identical genes are identical twins (or other multiple births) because they are formed from the splitting of a single fertilised egg cell. Yet there are variations even between identical twins (Figure 11.4). This is environmental variation and is caused by the influence of the environment – resulting from unplanned life events (such as scars from wounds) and from the individual's personal choices (hair styling, body piercings or tattoos, for example).

Some variations might result from a combination of genetic and environmental factors – height and weight, for example, have genetic components and are affected by diet.

Only naturally occurring variations can result in evolution, as environmental variations cannot be passed on.

Natural selection

The theory of natural selection describes a mechanism by which evolution is thought to occur. It is one of the most famous theories in science and was originated by Charles Darwin.

In the 1830s Darwin went on a five-year scientific voyage of discovery on the ship H.M.S. Beagle. He discovered many new species and noticed different species were variations on a common model, and the variations were linked with the organism's environment or lifestyle.

With another scientist Alfred Russel Wallace, Darwin developed his theory of natural selection to explain the evidence. This was his theory:

- Most animals and plants have many more offspring than can possibly survive, therefore the offspring are in a competition for survival. This is the idea of over-production.
- The offspring are not all the same; they show variation.
- Some varieties are better equipped for survival than others, because they are better suited to the environment. These will be more likely to survive to breed (survival of the fittest).
- Those that survive, breed and pass on their **heritable** characteristics to the next generation (at the time, people did not know about genes).
- Over many generations, the best characters become more common and eventually spread to all individuals. The species will have changed (evolved).

Darwin named his theory the theory of natural selection. It has been slightly refined over time but is still accepted as the mechanism for evolution by the majority of scientists.

Key term

Heritable Capable of being inherited (because it is a result of genes).

d) Protactinium-234 has a half-life of 77 s. The initial activity of a sample was measured to be 80 counts per second. Calculate the time for the activity to fall to 10 counts per second. [2]

4 The decay method and half-life of some radioisotopes used for medical purposes are shown in the table.

Radioisotope	Decay method	Half-life
Carbon-14	Beta	5730 years
Tellurium-133	Beta	12 minutes
Technecium-99	Gamma	6 hours
Cobalt-60	Beta and gamma	5 years
Americium-241	Alpha	432 years
Astatine-211	Alpha	7.2 hours

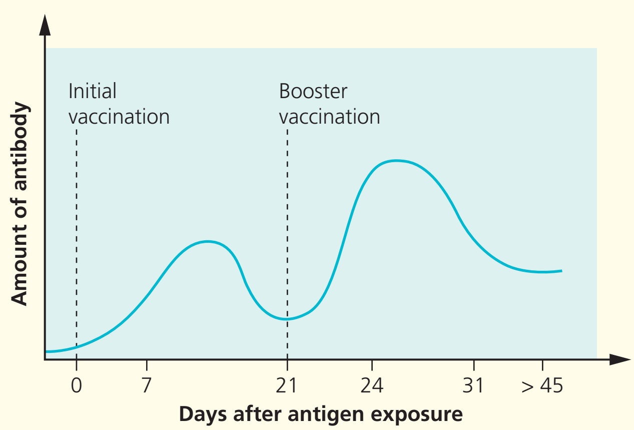
Select the most suitable radioisotope for the tasks below and give reasons for your choice. Only use data from the table.

a) Internal radiotherapy on a cancer tumour by injecting the radioisotope directly into the tumour. [3]

b) A source of gamma rays for external radiotherapy. [3]

c) A radiotracer for detecting blood flow through a kidney. [3]

5 Cattle were given a vaccine against ringworm, a fungal infection. The levels of antibodies in their blood were monitored over a period which included a booster vaccine. The results are shown below.



a) Which white blood cells produce antibodies? [1]

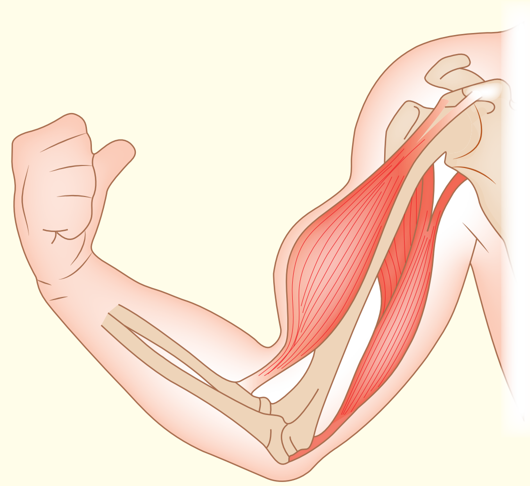
b) What term would be used to describe ringworm, as an organism which can cause disease? [1]

c) How do the blood cells recognise ringworm, so that antibody production is triggered? [1]

d) What evidence is there that the cows will need a further booster vaccine? [1]

e) Cattle are sometimes given antibiotics as a precaution, even though they are healthy. Explain why this practice is being discouraged in an effort to slow down the evolution of 'superbugs'. [3]

6 The diagram shows the bones and muscles in the upper arm.



a) Name the **two types** of joint shown in the diagram. [2]

b) State the conditions (contracted or relaxed) of the biceps and triceps muscles when the arm is straightened. [1]

c) The biceps and triceps are antagonistic muscles. State the meaning of this term. [1]

d) Name the following components of a joint like the shoulder joint:

i) The liquid that lubricates the joint. [1]

ii) The tissue that holds the bones of the joint together. [1]

iii) The tissue that reduces friction in the joint. [1]

7 Varicose veins are caused by a weakening and stretching of the walls of the veins and the valves become less effective. The veins of the legs become swollen and enlarged, appearing blue or dark purple.

a) What is the function of the valves in veins? [1]

b) Why is there no need for valves in arteries? [1]

c) Suggest why varicose veins are worse after a long period of standing. [2]

d) Suggest why the legs of a person with varicose veins feel heavy. [1]

e) Exercise is one aspect of the treatment of varicose veins. During exercise the muscles are constantly contracting. Suggest a reason why this might help with varicose veins. [1]

18 Materials for a purpose

When designing objects, designers have to take into account the properties of the materials that they intend to use. Using the wrong material can seriously affect the look, feel and functionality of objects.

Bonding

On an atomic and molecular level, materials consist of particles (atoms and molecules), bonded together. The main types of bonding are ionic, covalent and metallic.

Ionic bonding

Key terms

Ionic compound Formed between particles joined by ionic bonds.

Electrostatic attraction Ionic bonds are formed by this attraction between oppositely charged particles (ions).

Ionic compounds are ones where the particles are joined by ionic bonds. Ionic bonds are formed by the **electrostatic attraction** between oppositely charged particles (**ions**). Atoms are most stable when they have a full outer shell of electrons. Atoms with relatively full outer shells (non-metals) tend to gain electrons and so acquire a negative charge (becoming **anions**). Atoms with very few electrons in their outer shell (metals) tend to lose those electrons and become positively charged (or **cations**). If metallic and non-metallic atoms react together, the metal will donate one or more electron to the non-metal, and the two charged ions will then bond together. Figure 18.1 (called a 'dot and cross' diagram) illustrates this process for the formation of sodium chloride.

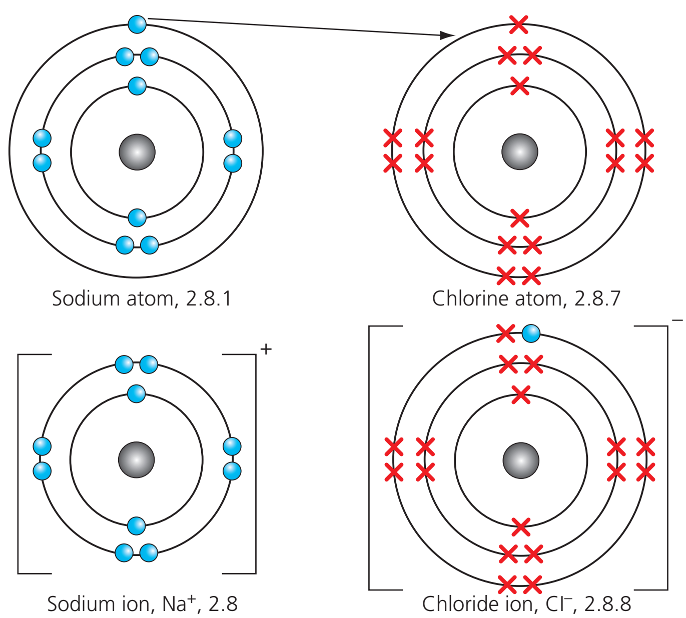


Figure 18.1 When sodium and chlorine atoms react, the sodium atom loses an electron forming a positively charged sodium ion, Na^+ (a cation) and the chlorine atom gains an electron forming a negatively charged chlorine ion, Cl^- (an anion)

and about 1 in 14 million (the same chance as winning the lottery) for the rest of the population. In addition, private companies may gain access to the data. This could mean that people are refused insurance policies due to the risk factors shown in their profile.

Experimental results

Information is collected through experiments and investigations. It is important that scientists understand what the data represents, how it can be displayed and what conclusions could be drawn.

Errors

Accuracy describes how close to the true value a result is. Inaccuracies can be caused by equipment, procedure or human errors. Errors can be classified as:

- Systematic – The same error occurs in every piece of data. For example, a top pan balance was not zeroed to 0 g before measurements were taken and displayed a value of 10 g. So, each mass that was measured would be 10 g greater than the accurate or true value. These errors are the easiest to correct – you find the inaccuracy and adjust every value accordingly.
- Random error – These are errors that are not consistent with each value, making the data difficult to correct. For example, when measuring the resistance of a wire, as the current flows, the wire heats up and this changes the resistance unpredictably. To reduce the effect of random errors, several reliable (similar) results can be used to calculate a mean value.

Displaying data

It is important that the data is displayed in such a way that patterns can be seen and conclusions can be drawn. All data from an investigation should initially be recorded in a suitable results table.

In results tables:

- All columns should be clearly labelled with the variable and, if appropriate, the units.
- Units should be in the column heading and not after each reading.
- The first column should be the independent variable and is completed before the experiment – you choose the values of this variable.
- The subsequent columns should be any dependent variables (observations or measurements) that you make during the investigation.
- If **anomalous results** are seen in the table, circle them and do not use them for further analysis.

If it is not possible to see any patterns in numerical data, it can be useful to use visual mathematical methods, for example:

- Pie chart – used when the independent variable is **categoric data** or **discontinuous data** and the dependent variable is a quantity (%).
- Bar chart – used when the independent variable is a category (x-axis) or discontinuous data and the dependent variable is **continuous data** (y-axis).

Key terms

Anomalous result A result that does not fit in the pattern of the other results.
Categoric data Data that is a category, usually a word, e.g. eye colour.
Continuous data Data that can take any value, e.g. height, handspan, temperature.
Discontinuous data Numerical data that can only have specific values and no intermediate values, e.g. shoe size.

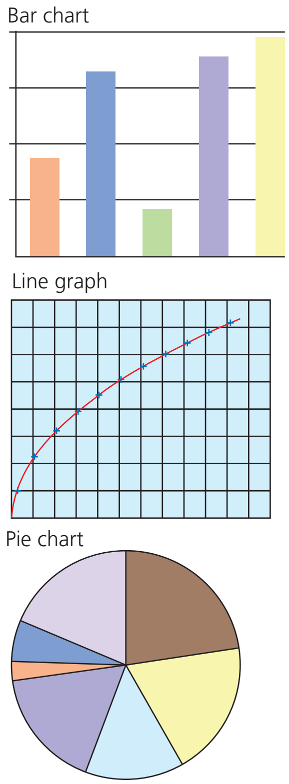


Figure 21.10 Data can be displayed in a variety of ways

- Line graph – used when both the independent (*x*-axis) and dependent variable (*y*-axis) are quantities. Use crosses not dots to plot points, with the size of the cross indicating your confidence in the accuracy of data; the bigger the cross, the less sure you are of the accuracy of the value. Once the graph is plotted, hold it at arm's length and see if there is a pattern in the data. If there is, draw a line of best fit which shows the pattern – do not draw dot to dot. If there are any points that do not fit the trend, circle them as anomalous points.

How to reach valid conclusions

The aim or objective of an investigation is often to answer a question. Results should be collected to allow you to meet the aim by answering the question. If an investigation actually measures what it set out to measure and gives results that can answer the question, we describe them as valid. Therefore, valid results can be used to support a conclusion which answers the question in the aim.

★ Worked example

In an experiment a student collected information about the age, height and shoe size of all pupils in class 5F. The aim of their experiment was to find out the average shoe size of children in the class.

1 Describe how the data could be used to determine the average shoe size of the children in the class.
2 Evaluate if the data they collected was valid.

Answers

1 Add all the shoes sizes together and divide by the number of students. Round the number to the nearest half shoe size as shoe sizes only come in whole or half sizes.
2 Although the data on the shoe size was valid as it was needed to answer the aim, not all the data is valid. This is because the data about height or age of the student was not needed to answer the aim.

Chapter summary

- Samples for analysis are collected so they are representative of the environment or material.
- Analytical techniques can be qualitative, semi-quantitative or quantitative.
- H The mole is a unit to measure the amount of substance.
- One mole of any substance has 6.02×10^{23} particles of that substance in it and the same numerical mass value as the relative atomic mass for single atoms or relative molecular mass for molecules but measured in grams.
- Chromatography is used to separate substances in a mixture to identify them using the retention time R_f.
- Chromatography techniques include paper, TLC, HPLC and GLC; all have a mobile phase and a stationary phase.
- Colorimetry is a qualitative technique which measures the transmittance of light through a solution to determine the concentration.
- Coloured test strips are a semi-quantitative colorimetry analysis.
- DNA is unique to individuals (except identical twins) and so genetic profiling can be used to identify criminals, family relationships and genetic diseases.
- Data must be recorded in a suitable way in order that patterns can be seen and valid conclusions drawn.
- Errors are inaccuracies in data and they can be both random and systematic errors.

Key terms

Nuclear fission When a large unstable nucleus breaks up spontaneously, or on impact with a neutron, releasing energy.

Chain reaction When one nuclear fission produces several neutrons which go on to produce further fissions, which also go on to produce further fissions, and so on.

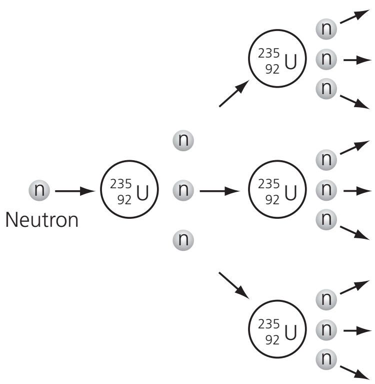


Figure 23.1 A chain reaction in uranium-235

Inside a nuclear reactor, U-235 nuclei can be broken up into large 'daughter' nuclei (rather than alpha decay), if they are bombarded by slow-moving neutrons – this process is called **nuclear fission**. A typical nuclear equation for this process is shown by:

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{141}_{56}\mathrm{Ba} + ^{92}_{36}\mathrm{Kr} + 3^{1}_{0}\mathrm{n}$$

During the fission, more free neutrons are produced, which themselves, in turn, can produce the fission of other U-235 nuclei, and so on, starting a process called a **chain reaction** (Figure 23.1).

An uncontrolled nuclear chain reaction can lead to an explosion which releases huge amounts of energy in a very short period of time. This mechanism is used in nuclear weapons. Nuclear reactors however, use control mechanisms to limit the speed of the chain reaction and release the energy much more slowly.

Test yourself

1. 1 atom of U-235 has a mass of 3.9×10^{-25} kg. How many atoms of U-235 are there in 1 kg? If each atom's nucleus can emit 3.2×10^{-11} J of energy, how much energy could 1 kg of U-235 produce?
2. 1 kg of U-235 could produce about 83 TJ (83×10^{12} J) of energy. By comparison, 1 kg of best coal could produce 35 MJ (35×10^{6} J). How much coal would you have to burn to get the same amount of energy as 1 kg of uranium-235?
3. Are there any other considerations when comparing coal and uranium as fuels for generating electricity?
4. Complete the following nuclear equations for fissions that occur inside a nuclear reactor:

   a) $^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{\dots}_{53}\mathrm{I} + ^{95}_{39}\mathrm{Y} + 3^{1}_{0}\mathrm{n}$

   b) $^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{144}_{56}\mathrm{Ba} + ^{90}_{36}\mathrm{Kr} + \dots ^{1}_{0}\mathrm{n}$

How does fission work?

The fission of U-235 breaks the nucleus up into two daughter nuclei, one with a nucleon number of about 137 and another with a nucleon number of about 95. On average, three neutrons are also produced, but this can be up to five or as low as one. The precise decay that any one U-235 nucleus undergoes depends on many factors, including the speed of the incoming fission neutron. We can represent one common decay by the nuclear equation:

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{144}_{56}\mathrm{Ba} + ^{89}_{36}\mathrm{Kr} + 3^{1}_{0}\mathrm{n}$$

In this example, the U-235 nucleus is impacted by a slow-moving neutron. The two daughter nuclei that are formed are barium-144 and krypton-89, and three other neutrons are produced that, when slowed down by a moderator inside a reactor, can go on to form three further fission events (Figure 23.2).

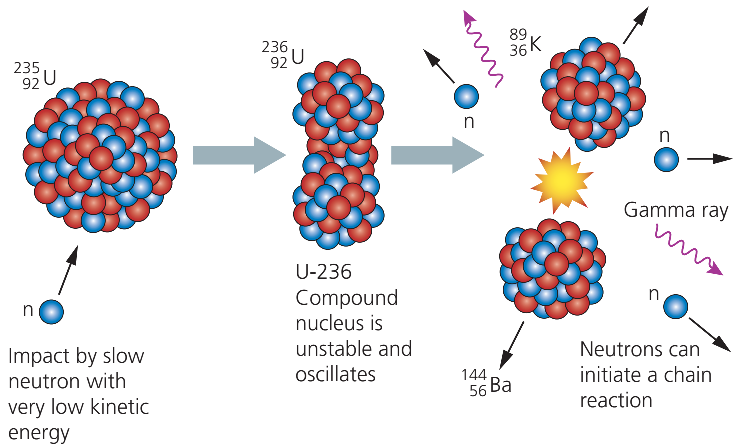


Figure 23.2 Uranium-235 decay

Many of the daughter fission products are also radioactive and they decay with a large range of half-lives, from iodine-129, which has a half-life of 15.7 million years, down to europium-155, with a half-life of 4.76 years. Nuclear fuel rods remain radioactive for a very long time and need to be stored very securely.

Test yourself

5 Use a Periodic Table to write nuclear equations to summarise the following fission reactions inside a nuclear fuel rod, occurring from the fission of uranium-235 from one neutron. The equations are of the form:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow \ldots + \ldots + \ldots ^{1}_{0}n$$

The fission products are:

a) xenon-140, strontium-94 and two neutrons
b) rubidium-90, caesium-144 and two neutrons
c) lanthanum-146, bromine-87 and three neutrons.

Reactor engineering

The nuclear fission process is only possible if the neutrons that are released from the fission of uranium-235 are moving slowly enough. If the neutrons are moving too fast, they will not cause fission. The slow-moving neutrons are called **thermal neutrons**. In order to slow down the fast-moving neutrons produced by the nuclear fission process, the fuel rods in the reactor are surrounded by a material called a **moderator**. Most nuclear reactors use water as the moderator (these are called pressurised water reactors or PWRs (Figure 23.3)), and others use graphite rods (graphite is a form of carbon). The advantage of using water as a moderator is that it can also act as the coolant and the mechanism of heat transfer for the reactor. The hot water is used to make steam which turns a turbine; this drives a generator that produces electricity. In

Key terms

Thermal neutrons Neutrons produced inside a nuclear reactor that are slowed down by a moderator so that they can produce further nuclear fissions.

Moderator Material such as water that slows down neutrons in a nuclear reactor so that they can produce further fissions.

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