Aston
ACADEMY

Seneca

Y10 Triple Paper 1 Revision

<u>When</u> → W/C 22nd/29th June

<u>You will be assessed on the following subject areas:</u>

- Chemistry (C1-2, C3-4, C5-7)
- Biology (B1-2, B3-4, B5-7, B8-9)
- Physics (P1-3, P4-5, P6-7)

Aston Science

Science Course Overview

Assessment Details	Your course – Exam Board AQA
	Combined Science (AQA Trilogy) – Students study Biology, Chemistry and Physics, with the scores being combined and 2 GCSE's being awarded. The qualifications will be graded on a 17-point scale: 1 – 1 to 5 – 5 (Foundation) or 4-3 to 9-9 (Higher). Separate Science will be awarded 3 GCSEs, one for Biology, Chemistry and Physics. The qualifications will be graded 1-5 (Foundation) or 3-9 (Higher).
	There are six 1hr 15-minute papers (1 hr 45-minutes for separates): Two biology, two chemistry and two physics.

Trials: W/C 22nd and 29th June

Combined: Biology Paper 1 and Physics Paper 1

Triple: Biology Paper 1, Chemistry Paper 1 and Physics Paper 1

Exam	Units	Sub-Units
Biology Paper 1	Cells and organisation	B1 Cell structure and transport
		B2 Cell division
		B3 Organisation and the digestive system
		B4 Organising animals and plants
	Disease and bioenergetics	B5 Communicable diseases
		B6 Preventing and treating disease
		B7 non-communicable diseases
		B8 Photosynthesis
		B9 Respiration
Chemistry Paper 1	Atoms, bonding, and moles	C1 Atomic structure
		C2 The periodic table
		C3 Structure and bonding
		C4 Chemical calculations
	Chemical reactions and energy changes	C5 Chemical changes
		C6 Electrolysis
		C7 Energy changes
Physics Paper 1	Energy and energy resources	P1 Conservation and dissipation of energy
		P2 Energy transfer by heating
		P3 Energy resources
	Particles at work	P4 Electric circuits
		P5 Electricity in the home
		P6 Molecules and matter
		P7 Radioactivity

BBC Bitesize AQA Combined Science	**BBC Bitesize AQA - Biology**	**BBC Bitesize AQA – Chemistry**	**BBC Bitesize AQA - Physics**	**AQA Exam Paper YouTube videos***

*These videos go through all the content for each paper in roughly 30 minutes (per video). Make sure to select the AQA Paper 1 videos, NOT OCR or Edexcel.

Revision Strategies

As you approach your first set of trial exams, we recognise that you are revising multiple subjects and that time is limited. In Science, progress is built through revising *better* not revising *more*. Below are focussed revision strategies that can be followed using the weekly/bi-weekly "3-2-1" structure.

What is the "3-2-1" structure?

- Three 20 minutes: learn + questions sessions
- Two 10 minutes: retrieval (no notes) sessions
- One 20 minute: timed exam questions + self-mark + improve session
- Each session should focus on **one small topic or skill.** Focus on **weak** topics, not favourites

Effective Active Revision Strategies

Flash Cards

- Flash cards help your child actively recall key facts and definitions, which strengthens memory and boosts confidence in exams.
- You can quiz your child using their flash cards, turning revision into a quick, focused, and engaging activity at home.

Exam Questions / Past Papers

- Practising past papers helps your child become familiar with exam formats and improves their ability to manage time under pressure.
- By reviewing mark schemes and examiner reports, your child can learn exactly what examiners are looking for and how to gain top marks.

Blurting

- Blurting involves your child writing down everything they know about a topic from memory, which reveals gaps in their knowledge and strengthens recall.
- Encourage your child to check their notes afterward to see what they missed — this targeted approach makes future revision more effective.

Feynman Technique

- With the Feynman Technique, your child explains a topic in simple terms, helping them deeply understand the content rather than just memorising it.
- You can support them by asking them to "teach" you a topic — if they can explain it clearly, they truly understand it.

2-3-5-7 Method

- The 2-3-5-7 method spaces revision over increasing intervals (after 2, 3, 5, and 7 days), helping information stick in your child's long-term memory.
- Supporting your child in planning their revision using this method can make their study time more efficient and reduce last-minute cramming stress

*Flash cards can be done using free apps which you can download from the Appstore, as well as on paper!

Past Papers

The links below will take you directly to past papers for each of the science exams. Make sure to choose the AQA exam board! Mark schemes can also be accessed using these links.

All - https://www.physicsandmathstutor.com/past-papers/gcse-science/

Combined Science - https://www.aqa.org.uk/subjects/science/gcse/science-8464/assessment-resources

Triple Science (Biology) - https://www.aqa.org.uk/subjects/biology/gcse/biology-8461/assessment-resources

Triple Science (Chemistry) – https://www.aqa.org.uk/subjects/chemistry/gcse/chemistry-8462/assessment-resources

Triple Science (Physics) - https://www.aqa.org.uk/subjects/physics/gcse/physics-8463/assessment-resources?f.Resource%20type%7C6=Question%20papers&sort=title&num_ranks=10&start_rank=1

Checklist of Tasks to complete before the June Trial Exams

- ☐ Create a revision timetable for science
- ☐ Watched the AQA Biology Paper 1 in 25 minutes video (Combined and Triple)
- ☐ Watched the AQA Chemistry Paper 1 in 30 minutes video (Triple)
- ☐ Watched the AQA Physics Paper 1 in 40 minutes video (Combined and Triple)
- ☐ Completed 30 minutes of past paper practice for Biology Paper 1 (Combined and Triple)
- ☐ Completed 30 minutes of past paper practice for Chemistry Paper 1 (Triple)
- ☐ Completed 30 minutes of past paper practice for Physics Paper 1 (Combined and Triple)

REVISION TIMETABLE – week beginning

Date → / ↓ Time	Mon	Tues	Weds	Thurs	Fri
3.00-3:30pm					
3:30-4.00pm					
4.00-5.00pm					
5.00-5:30pm					
5:30-6:30pm					
6:30-7:30pm					
7:30-8.00pm					
8.00-9.00pm					

Date → / ↓ Time	Sat	Sun
9.00-10.00am		
10.00-11.00am		
11.00-11:30am		
11:30-12:30pm		
12:30-1.00pm		
1.00-2.00pm		
2.00-3.00pm		
3.00-3:30pm		
3:30-4.00pm		
4.00-5.00pm		
5.00-5:30pm		
5:30-6:30pm		
6:30-7:30pm		
7:30-8.00pm		
8.00-9.00pm		

Focus Subjects to revise this week:

-
-
-

Topics that I find most difficult to focus on:

-
-
-

The teachers who I need to ask for past papers and revision materials from:

-
-
-

Chapter 1: Atomic structure

Knowledge organiser

Development of the model of the atom

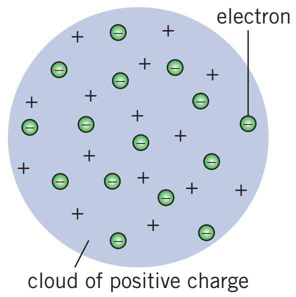
Dalton's model

John Dalton thought of the **atom** as a solid sphere that could not be divided into smaller parts. His model did not include **protons**, **neutrons**, or **electrons**.

The plum pudding model

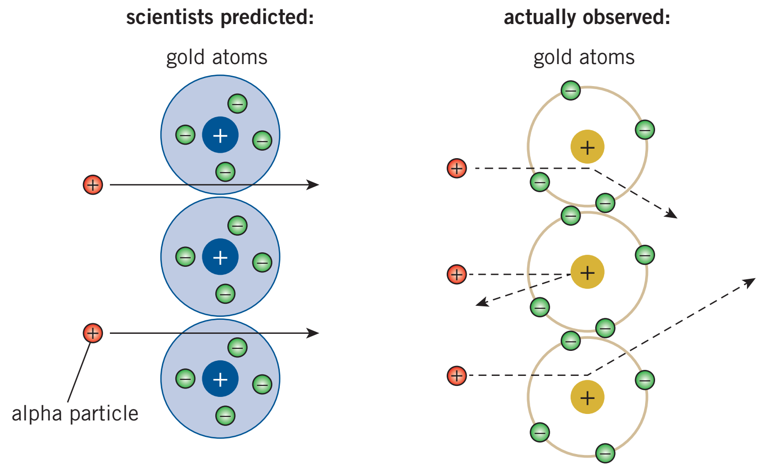
Scientists' experiments resulted in the discovery of sub-atomic charged particles. The first to be discovered were electrons – tiny, negatively charged particles.

The discovery of electrons led to the plum pudding model of the atom – a cloud of positive charge, with negative electrons embedded in it. Protons and neutrons had not yet been discovered.



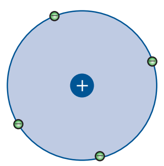
Alpha scattering experiment

1. Scientists fired small, positively charged particles (called alpha particles) at a piece of gold foil only a few atoms thick.
2. They expected the alpha particles to travel straight through the gold.
3. They were surprised that some of the alpha particles bounced back and many were deflected (alpha scattering).
4. To explain why the alpha particles were repelled the scientists suggested that the positive charge and mass of an atom must be concentrated in a small space at its centre. They called this space the **nucleus**.



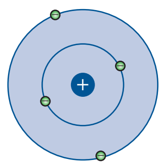
Nuclear model

Scientists replaced the plum pudding model with the nuclear model and suggested that the electrons **orbit** the nucleus, but not at set distances.



Electron shell (Bohr) model

Niels Bohr calculated that electrons must orbit the nucleus at fixed distances. These orbits are called **shells** or **energy levels**.



The proton

Further experiments provided evidence that the nucleus contained smaller particles called protons. A proton has an opposite charge to an electron.

The neutron

James Chadwick carried out experiments that gave evidence for a particle with no charge. Scientists called this the neutron and concluded that the protons and neutrons are in the nucleus, and the electrons orbit the nucleus in shells.

Relative mass

One property of protons, neutrons, and electrons is **relative mass** – their masses compared to each other. Protons and neutrons have the same mass, so are given a relative mass of 1. It takes almost 2000 electrons to equal the mass of a single proton – their relative mass is so small that we can consider it as 0.

Size

The atom has a radius of 1×10^{-10} m. Nuclei (plural of nucleus) are around 10 000 times smaller than atoms and have a radius of around 1×10^{-14} m.

Elements and compounds

Elements are substances made of one type of atom. Each atom of an element will have the same number of protons.

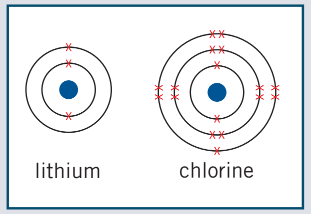
Compounds are made of different types of atoms chemically bonded together. The atoms in a compound have different numbers of protons.

Drawing atoms

Electrons in an atom are placed in fixed shells. You can put

- up to two electrons in the first shell
- eight electrons each in the second and third shells.

You must fill up a shell before moving on to the next one.



Mixtures

- A mixture consists of two or more elements or compounds that are not chemically combined together.
- The substances in a mixture can be separated using physical processes.
- These processes do not use chemical reactions.

Separating mixtures

- filtration – insoluble solids and a liquid
- crystallisation – soluble solid from a solution
- simple distillation – solvent from a solution
- fractional distillation – two liquids with similar boiling points
- paper chromatography – identify substances from a mixture in solution

Atoms and particles

	Relative charge	Relative mass	
Proton	+1	1	= atomic number
Neutron	0	1	= mass number – atomic number
Electron	–1	0 (very small)	= same as the number of protons

All atoms have equal numbers of protons and electrons, meaning they have no overall charge:

total negative charge from electrons = total positive charge from protons

Isotopes

Atoms of the same element can have a different number of neutrons, giving them a different overall mass number. Atoms of the same element with different numbers of neutrons are called **isotopes**.

The **relative atomic mass** is the average mass of all the atoms of an element:

$$\text{relative atomic mass} = \frac{(\text{abundance of isotope 1} \times \text{mass of isotope 1}) + (\text{abundance of isotope 2} \times \text{mass of isotope 2})...}{100}$$

Key terms

Make sure you can write a definition for these key terms.

abundance, atom, atomic number, aqueous, compound, electron, element, energy level, isotope, neutron, nucleus, orbit, product, proton, reactant, relative atomic mass, relative charge, relative mass, shell

Chapter 1: Atomic structure

Knowledge organiser

Development of the model of the atom

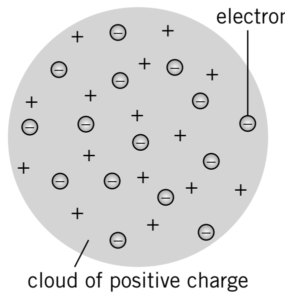
Dalton's model

John Dalton thought of the ________ as a solid sphere that could not be divided into smaller parts. His model did not include ________, ________, or ________.

The plum pudding model

Scientists' experiments resulted in the discovery of sub-atomic ________ particles. The first to be discovered were electrons – tiny, ________ charged particles.

The discovery of electrons led to the ________________ of the atom – a cloud of ________ charge, with negative ________ embedded in it. ________ and ________ had not yet been discovered.



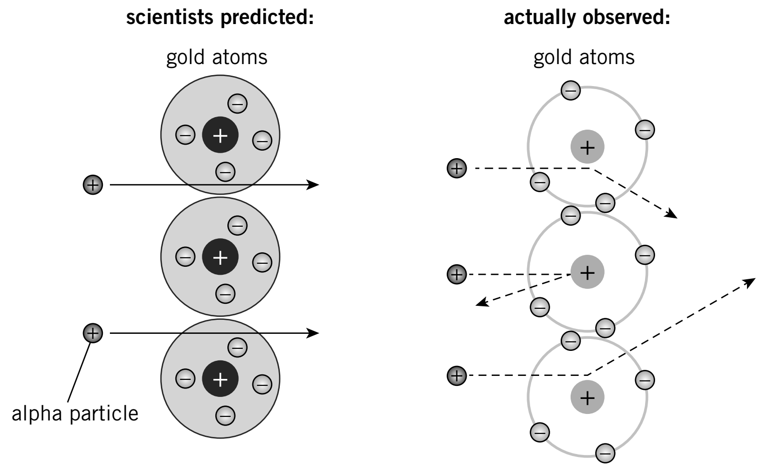
Alpha scattering experiment

1 Scientists fired small, ________ charged particles (called ______ particles) at a piece of ______ foil only a few atoms thick.

2 They expected the alpha particles to travel ______ through the gold.

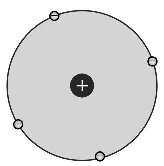
3 They were surprised that some of the alpha particles ______ back and many were ______ (alpha scattering).

4 To explain why the alpha particles were repelled the scientists suggested that the positive charge and mass of an atom must be concentrated in a small space at its centre. They called this space the ________.



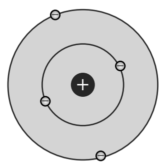
Nuclear model

Scientists replaced the plum pudding model with the nuclear model and suggested that the electrons ______ the nucleus, but not at set ______.



Electron shell (Bohr) model

Niels Bohr calculated that electrons must orbit the nucleus at fixed distances. These orbits are called ______ or ________ ________.



The proton

Further experiments provided evidence that the nucleus contained smaller particles called ______. A proton has an ______ charge to an electron.

The neutron

James Chadwick carried out experiments that gave evidence for a particle with no charge. Scientists called this the ______ and concluded that the ______ and ______ are in the nucleus, and the electrons orbit the nucleus in ______.

Relative mass

One property of protons, neutrons, and electrons is ________ – their masses compared to each other. Protons and neutrons have the same mass, so are given a relative mass of ______. It takes almost ______ electrons to equal the mass of a single proton – their relative mass is so small that we can consider it as ______.

Size

The atom has a radius of ______. ______ (plural of nucleus) are around ______ times smaller than atoms and have a radius of around ______.

Elements and compounds

Elements are substances made of one type of atom. Each atom of an element will have the same number of ______.

________ are made of different types of atoms chemically ______ together. The atoms in a compound have ________ numbers of protons.

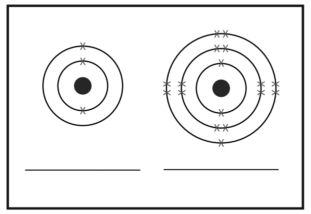
Drawing atoms

Electrons in an atom are placed in fixed shells. You can put

- up to ______ electrons in the first shell
- eight electrons each in the ________ and ________ shells.

You must fill up a shell before moving on to the next one.

Name the elements



Mixtures

- A mixture consists of ________ elements or compounds that are not ________ combined together.
- The substances in a mixture can be ________ using physical processes.
- These processes do not use ________ reactions.

Separating mixtures

- ________ – insoluble solids and a liquid
- ________ – soluble solid from a solution
- ____________ – solvent from a solution
- ____________ – two liquids with similar boiling points
- ____________ – identify substances from a mixture in solution

Atoms and particles

	Relative charge	Relative mass	
Proton			= ______ number
Neutron			= ______ number – ______ number
Electron			= same as the number of ______

All atoms have ______ numbers of protons and electrons, meaning they have ______ overall charge:

total negative charge from electrons = total positive charge from protons

Isotopes

Atoms of the same element can have a different number of ________, giving them a different overall ________.
Atoms of the same element with ________ numbers of neutrons are called **isotopes**.

The **relative atomic mass** is the average ______ of all the atoms of an element:

$$\text{relative atomic mass} = \frac{(\text{abundance of isotope 1} \times \text{mass of isotope 1}) + (\text{abundance of isotope 2} \times \text{mass of isotope 2})\ldots}{100}$$

Key terms **Make sure you can write a definition for these key terms.**

abundance atom atomic number aqueous compound electron element energy level isotope neutron nucleus orbit product proton reactant relative atomic mass relative charge relative mass shell

Chapter 1: Atomic structure

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	C1 questions	Answers
1	What is an atom?	
2	What is Dalton's model of the atom?	
3	What is the plum pudding model of the atom?	
4	What did scientists discover in the alpha scattering experiment?	
5	Describe the nuclear model of the atom.	
6	What did Niels Bohr discover?	
7	What did James Chadwick discover?	
8	Where are protons and neutrons?	
9	What is the relative mass of each sub-atomic particle?	
10	What is the relative charge of each sub-atomic particle?	
11	How can you find out the number of protons in an atom?	
12	How can you calculate the number of neutrons in an atom?	
13	Why do atoms have no overall charge?	
14	How many electrons would you place in the first, second, and third shells?	
15	What is an element?	
16	What is a compound?	
17	What is a mixture?	
18	What are isotopes?	
19	What are the four physical processes that can be used to separate mixtures?	
20	What is relative mass?	

Chapter 2: The Periodic Table

Knowledge organiser

Development of the Periodic Table

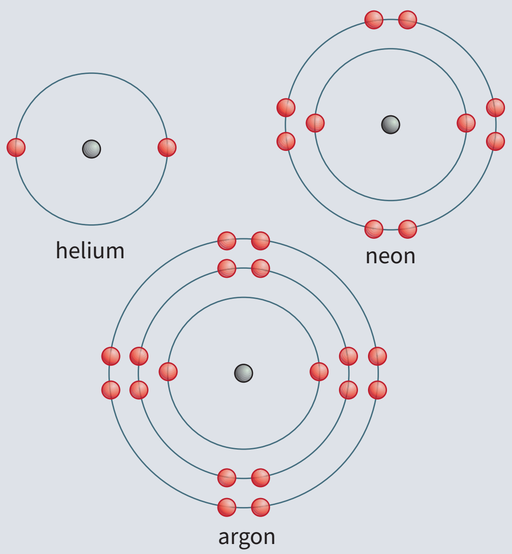
The Periodic Table has changed over time as scientists have organised it differently. Mendeleev was able to accurately predict the properties of undiscovered elements based on the gaps in the table.

	First lists of elements	Mendeleev's Periodic Table	Modern Periodic Table
How are elements ordered?	by atomic mass	normally by atomic mass but some elements were swapped around	by atomic number
Are there gaps?	no gaps	gaps left for undiscovered elements	no gaps – all elements up to a certain atomic number have been discovered
How are elements grouped?	not grouped	grouped by chemical properties	grouped by the number of electrons in the outer shells
Metals and non-metals	no clear distinction	no clear distinction	metals to the left, non-metals to the right
Problems	some elements grouped inappropriately	incomplete, with no explanation for why some elements had to be swapped to fit in the appropriate groups	—

Group 0

Elements in **Group 0** are called the **noble gases**. Noble gases have the following properties:

- full outer shells with eight electrons, so do not need to lose or gain electrons
- are very unreactive (**inert**) so exist as single atoms as they do not bond to form molecules
- boiling points that increase down the group.



Key terms

Make sure you can write a definition for these key terms.

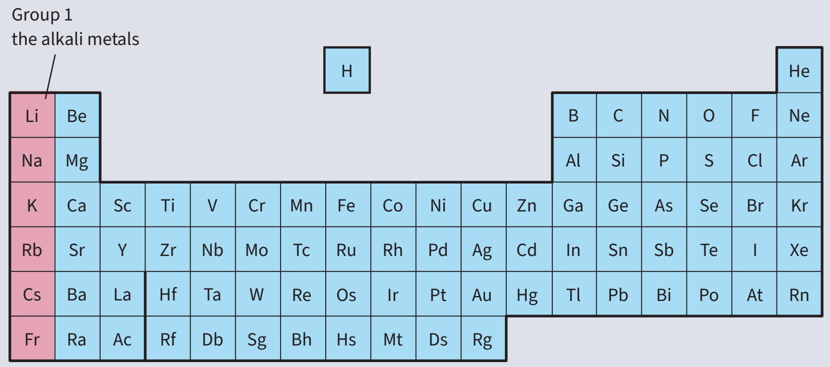
alkali metals · chemical properties · displacement · groups · halogens · inert · isotopes · noble gas · organised · Periodic Table · reactivity · undiscovered · unreactive

Group 1 elements

Group 1 elements react with oxygen, chlorine, and water, for example:

lithium + oxygen ➞ lithium oxide
lithium + chlorine ➞ lithium chloride
lithium + water ➞ lithium hydroxide + hydrogen

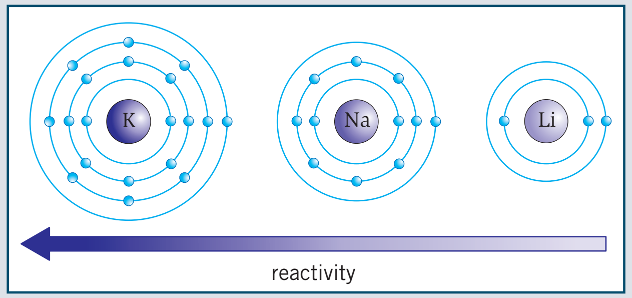
Group 1 elements are called **alkali metals** because they react with water to form an alkali (a solution of their metal hydroxide).



Group 1 properties

Group 1 elements all have one electron in their outer shell. **Reactivity** increases down Group 1 because as you move down the group:

- the atoms increase in size
- the outer electron is further away from the nucleus, and there are more shells shielding the outer electron from the nucleus
- the electrostatic attraction between the nucleus and the outer electron is weaker so it is easier to lose the one outer electron
- the melting point and boiling point decreases down Group 1.



Group 7 elements

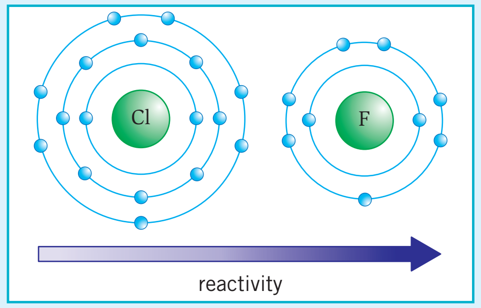
Group 7 elements are called the **halogens**. They are non-metals that exist as molecules made up of pairs of atoms.

Name	Formula	State at room temperature	Melting point and boiling point	Reactivity
fluorine	F_2	gas	increases down the group	decreases down the group
chlorine	Cl_2	gas		
bromine	Br_2	liquid		
iodine	I_2	solid		

Group 7 reactivity

Reactivity decreases down Group 7 because as you move down the group:

- the atoms increase in size
- the outer shell is further away from the nucleus, and there are more shells between the nucleus and the outer shell
- the electrostatic attraction from the nucleus to the outer shell is weaker so it is harder to gain one electron to fill the outer shell.



Group 7 displacement

More reactive Group 7 elements can take the place of less reactive ones in a compound. This is called **displacement**.

For example, fluorine displaces chlorine as it is more reactive:

fluorine + potassium chloride ➞ potassium fluoride + chlorine

Chapter 2: The Periodic Table

Knowledge organiser

Development of the Periodic Table

The Periodic Table has changed over time as scientists have organised it differently. Mendeleev was able to accurately predict the properties of undiscovered elements based on the gaps in the table.

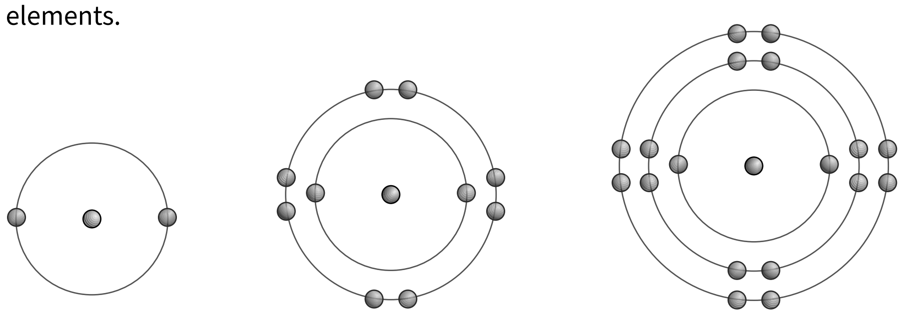
	First lists of elements	Mendeleev's Periodic Table	Modern Periodic Table
How are elements ordered?			
Are there gaps?			
How are elements grouped?			
Metals and non-metals			
Problems			

Group 0

Elements in **Group 0** are called the ________ ________. They have the following properties:

- full outer shells with ________ electrons, so do not need to ________ or ________ electrons
- are very ________________ so exist as single atoms as they do not bond to form molecules
- boiling points that __________ down the group.

Name the group 0 elements.



__________ __________ __________

Key terms Make sure you can write a definition for these key terms.

alkali metals chemical properties displacement groups halogens inert isotopes noble gas organised Periodic Table reactivity undiscovered unreactive

Group 1 elements

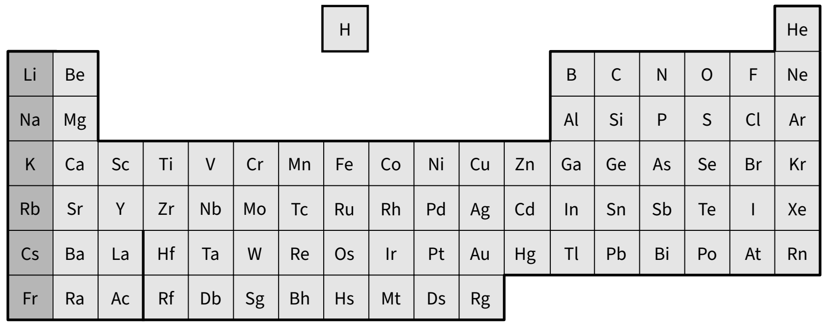
Group 1 elements react with oxygen, chlorine, and water, for example:

lithium + oxygen → ______________

lithium + chlorine → ______________

lithium + water → ______________ + _________

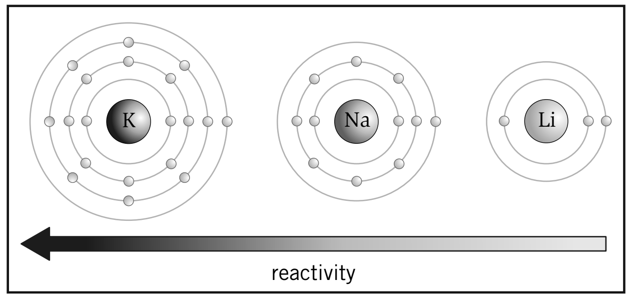
Group 1 elements are called ______________ because they react with water to form an alkali (a solution of their metal hydroxide).



Group 1 properties

Group 1 elements all have ________ electron in their outer shell. **Reactivity** ________ down Group 1 because as you move down the group:

- the atoms ________ in size
- the outer electron is further away from the nucleus, and there are more shells ________ the outer electron from the nucleus
- the ________ attraction between the nucleus and the outer electron is ______ so it is easier to lose the one ________ electron
- the melting point and boiling point ________ down Group 1.



Group 7 elements

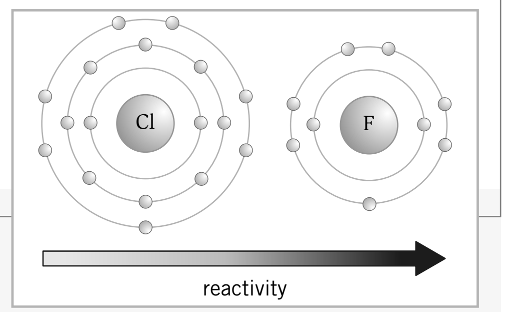
Group 7 elements are called the ________. They are non-metals that exist as molecules made up of ________ of atoms.

Name	Formula	State at room temperature	Melting point and boiling point	Reactivity
fluorine				
chlorine				
bromine				
iodine				

Group 7 reactivity

Reactivity decreases down Group 7 because as you move down the group:

- the atoms ________ in size
- the outer shell is further away from the nucleus, and there are more ________ between the nucleus and the outer shell
- the electrostatic attraction from the nucleus to the outer shell is ________ so it is harder to ________ one electron to fill the outer shell.



Group 7 displacement

More reactive Group 7 elements can take the place of less reactive ones in a compound. This is called ___________.

For example, fluorine displaces chlorine as it is more ________:

fluorine + potassium chloride → ___________ + ___________

Chapter 2: The Periodic Table

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

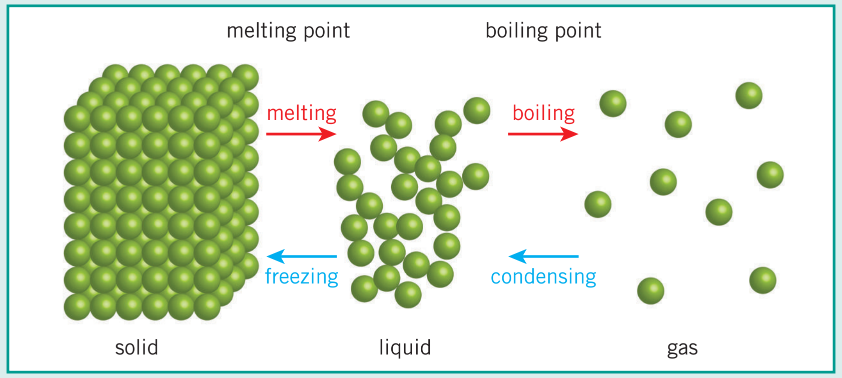
	C2 questions	Answers
1	How is the modern Periodic Table ordered?	
2	How were the early lists of elements ordered?	
3	Why did Mendeleev swap the order of some elements?	
4	Why did Mendeleev leave gaps in his Periodic Table?	
5	Why do elements in a group have similar chemical properties?	
6	Where are metals and non-metals located on the Periodic Table?	
7	What name is given to the Group 1 elements?	
8	Why are the alkali metals named this?	
9	Give the general equations for the reactions of alkali metals with oxygen, chlorine, and water.	
10	How does the reactivity of the alkali metals change down the group?	
11	Why does the reactivity of the alkali metals increase down the group?	
12	What name is given to the Group 7 elements?	
13	Give the formulae of the first four halogens.	
14	How do the melting points of the halogens change down the group?	
15	How does the reactivity of the halogens change down the group?	
16	Why does the reactivity of the halogens decrease down the group?	
17	What is a displacement reaction?	
18	What name is given to the Group 0 elements?	
19	Why are the noble gases inert?	
20	How do the melting points of the noble gases change down the group?	

Chapter 3: Bonding 1

Knowledge organiser

Particle model

The three states of matter can be represented in the particle model.



(HT only) This model assumes that:

- there are no forces between the particles
- that all particles in a substance are spherical
- that the spheres are solid.

The amount of energy needed to change the state of a substance depends on the forces between the particles. The stronger the forces between the particles, the higher the melting or boiling point of the substance.

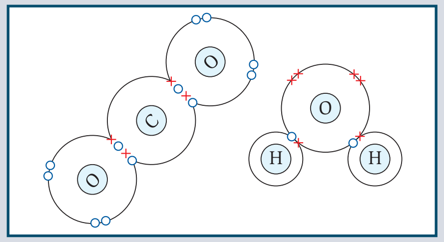
Covalent bonding

Atoms can share or transfer electrons to form strong chemical bonds.

A **covalent bond** is when electrons are *shared* between **non-metal** atoms.

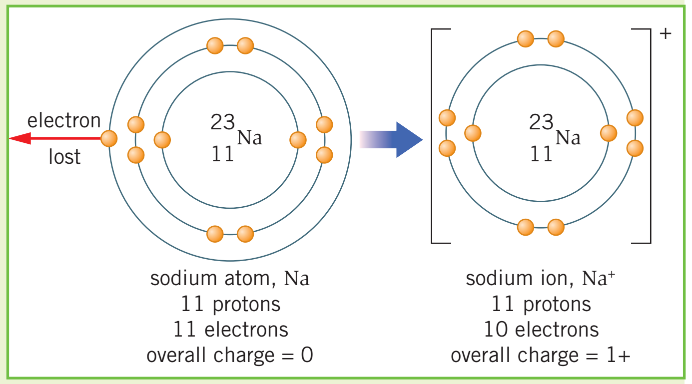
The number of electrons shared depends on how many extra electrons an atom needs to make a full outer shell.

If you include electrons that are shared between atoms, each atom has a full outer shell. **Single bond** = each atom shares one pair of electrons. **Double bond** = each atom shares two pairs of electrons.



Ions

Atoms can gain or lose electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an **ion**.



Conductivity

Solid ionic substances do not conduct electricity because the ions are fixed in position and not free to carry charge.

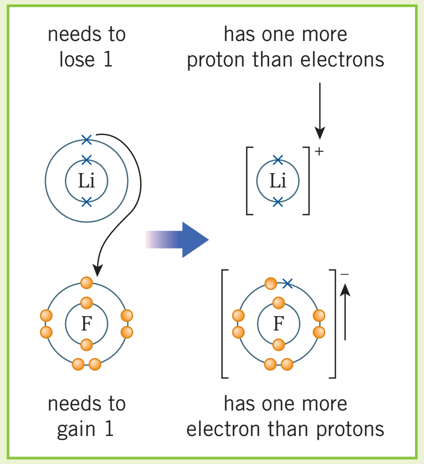
When melted or dissolved in water, ionic substances do conduct electricity because the ions are free to move and carry charge.

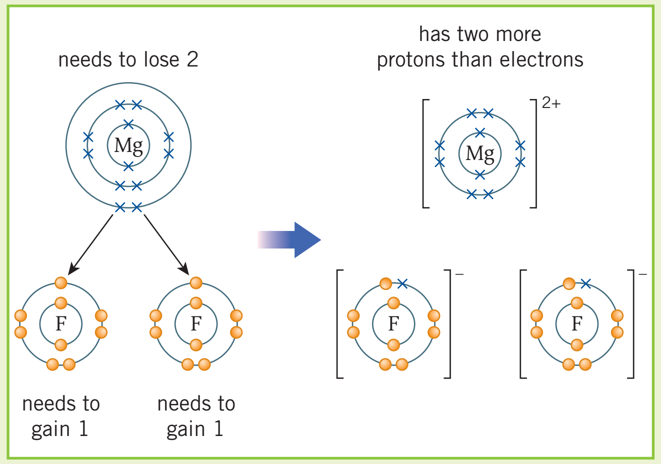
Melting points

Ionic substances have high melting points because the electrostatic force of attraction between oppositely charged ions is strong and so requires lots of energy to break.

Ionic bonding

When metal atoms react with non-metal atoms they **transfer** electrons to the non-metal atom.

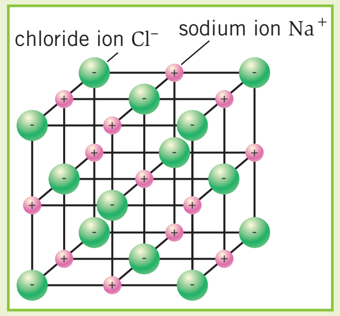




Metal atoms lose electrons to become positive ions. Non-metal atoms gain electrons to become negative ions.

Giant ionic lattice

When metal atoms transfer electrons to non-metal atoms you end up with positive and negative ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called ionic bonding.

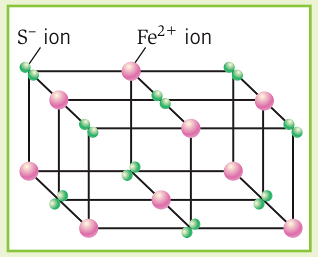


The electrostatic force of attraction works in all directions, so many billions of ions can be bonded together in a 3D structure.

Formulae

The formula of an ionic substance can be worked out

1. from its bonding diagram: for every one magnesium ion there are two fluoride ions – so the formula for magnesium fluoride is MgF_2
2. from a lattice diagram: there are nine Fe^{2+} ions and 18 S^- ions – simplifying this ratio gives a formula of FeS_2



Covalent structures

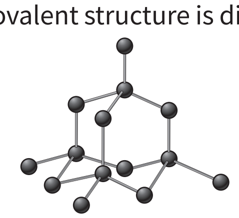
There are three main types of covalent structure:

Structure and bonding

Giant covalent

Many billions of atoms, each one with a strong covalent bond to a number of others.

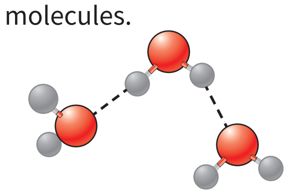
An example of a giant covalent structure is diamond.



Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak **intermolecular forces**.

For example, water is made of small molecules.



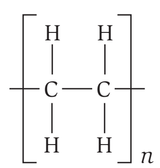
Large molecules

Many repeating units joined by covalent bonds to form a chain.

The small section is bonded to many identical sections to the left and right. The 'n' represents a large number.

Separate chains are held together by intermolecular forces that are stronger than in small molecules.

Polymers are examples of long molecules.



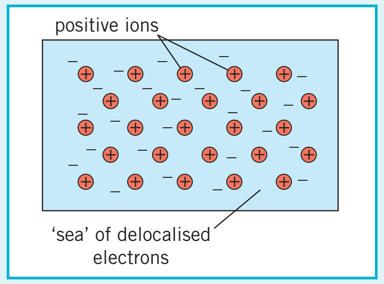
Metals: structure and properties

The atoms that make up metals form layers. The electrons in the outer shells of the atoms are **delocalised** – this means they are free to move through the whole structure.

The positive metal ions are then attracted to these delocalised electrons by the electrostatic force of attraction.

Some important properties of metals are:

- pure metals are **malleable** because the layers can slide over each other
- they are good **conductors** of electricity and of thermal energy because delocalised electrons are free to move through the whole structure
- they have high melting and boiling points because the electrostatic force of attraction between metal ions and delocalised electrons is strong so lots of energy is needed to break it.



Chapter 3: Bonding 2

Knowledge organiser

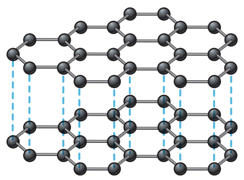
Properties			
	High melting and boiling points because the strong covalent bonds between the atoms must be broken to melt or boil the substances. This requires a lot of energy. Solid at room temperature.	Low melting and boiling points because only the intermolecular forces need to be overcome to melt or boil the substances, not the bonds between the atoms. This does not require a lot of energy as the intermolecular forces are weak. Normally gaseous or liquid at room temperature.	Melting and boiling points are low compared to giant covalent substances but higher than for small molecules. Large molecules have stronger intermolecular forces than small molecules, which require more energy to overcome. Normally solid at room temperature.

Most covalent structures do not conduct electricity because they do not have **delocalised electrons** or ions that are free to move to carry charge.

Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

Structure



Made only of carbon – each carbon atom bonds to three others, and forms hexagonal rings in layers. Each carbon atom has one spare electron, which is delocalised and therefore free to move around the structure.

Hardness

The layers can slide over each other because they are not covalently bonded. Graphite is therefore softer than diamond, even though both are made only of carbon, as each atom in diamond has four strong covalent bonds.

Conductivity

The delocalised electrons are free to move through graphite, so can carry charges and allow an electrical current to flow. Graphite is therefore a conductor of electricity.

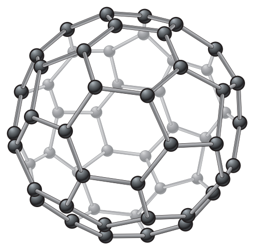
Graphene

Graphene consists of only a single layer of graphite. Its strong covalent bonds make it a strong material that can also conduct electricity. It could be used in composites and high-tech electronics.

Fullerenes

- hollow cages of carbon atoms bonded together in one molecule
- can be arranged as a sphere or a tube (called a **nanotube**)
- molecules held together by weak intermolecular forces, so can slide over each other
- conduct electricity

Spheres

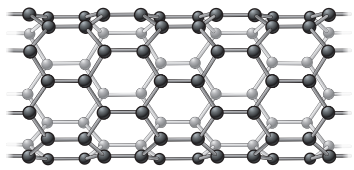


Buckminsterfullerene was the first fullerene to be discovered, and has 60 carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as lubricants and in drug delivery.

Nanotubes

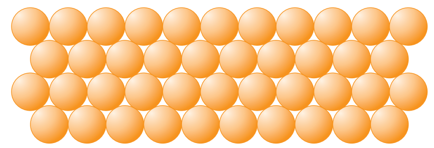


The carbon atoms in nanotubes are arranged in cylindrical tubes.
Their high **tensile strength** (they are difficult to break when pulled) makes them useful in electronics.

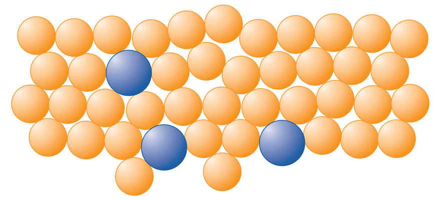
Alloys

Pure metals are often too soft to use as they are. Adding atoms of a different element can make the resulting mixture harder because the new atoms will be a different size to the pure metal's atoms. This will disturb the regular arrangement of the layers, preventing them from sliding over each other.

The harder mixture is called an **alloy**.



pure iron



iron alloy

Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	1×10^{-4} m	0.0001 m
coarse particles (e.g., dust)	PM_{10}	10 μm	1×10^{-5} m	0.00001 m
fine particles	$PM_{2.5}$	100 nm	1×10^{-7} m	0.0000001 m
nanoparticles	$< PM_{2.5}$	1 to 100 nm	1×10^{-9} to 1×10^{-7} m	0.000000001 m to 0.0000001 m

PM stands for **particulate matter** and is another way of measuring very small particles.

Uses of nanoparticles

Nanoparticles often have very different properties to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in healthcare, electronics, cosmetics, and as catalysts.

However, nanoparticles have the potential to be hazardous to health and to ecosystems, so it is important that they are researched further.

Key terms Make sure you can write a definition for these key terms.

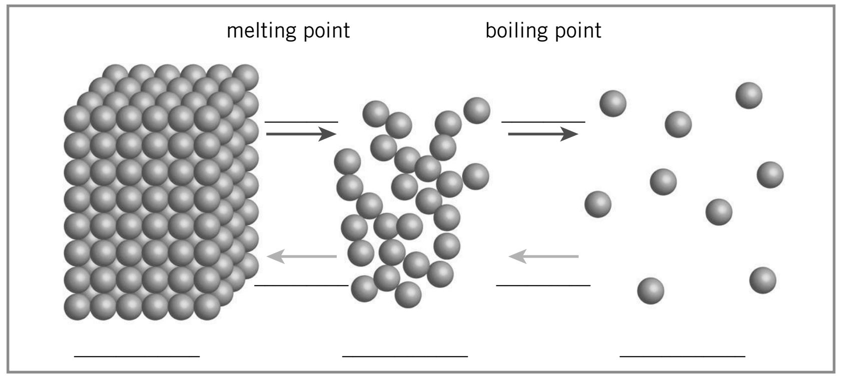
conductivity, conductor, delocalised electron, electrostatic force of attraction, ion, lattice, layer, malleable, nanoparticle, particulate matter, surface area to volume ratio, transfer

Chapter 3: Bonding 1

Knowledge organiser

Particle model

The three states of matter can be represented in the particle model.



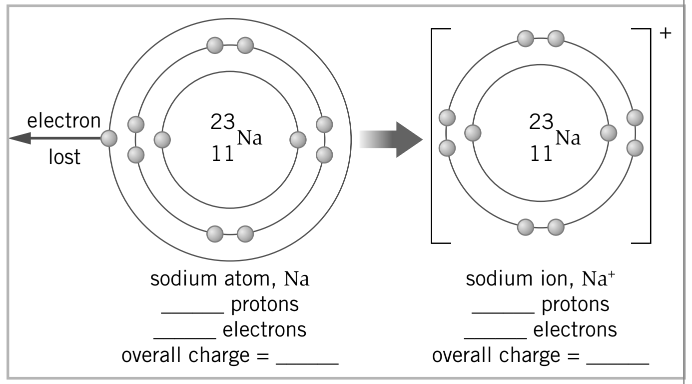
(HT only) This model assumes that:

-
-
-

The amount of energy needed to change the state of a substance depends on the ____ between the particles. The stronger the ____ between the particles, the ____ the melting or boiling point of the substance.

Ions

Atoms can ____ or ____ electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an ____.



Conductivity

Solid ionic substances do not ____ electricity because the ions are fixed in position and not free to carry ____.

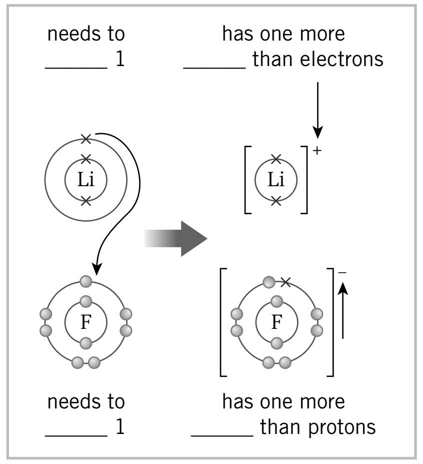
When ____ or ____ in water, ionic substances do ____ electricity because the ions are ____ to move and carry charge.

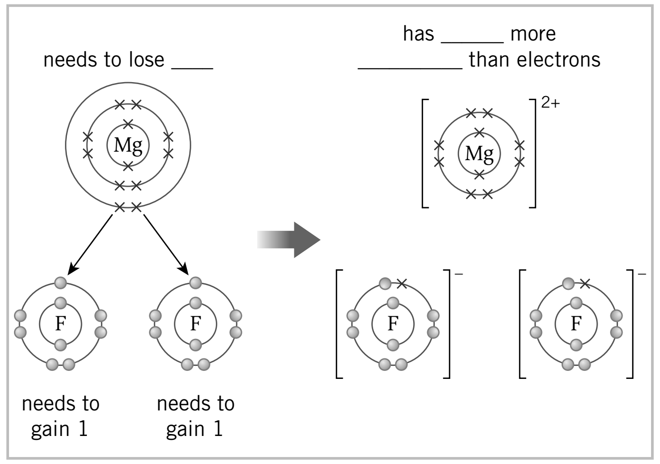
Melting points

Ionic substances have ____ melting points because the ____ force of attraction between ____ charged ions is strong and so requires lots of ____ to break.

Ionic bonding

When metal atoms react with non-metal atoms they ____ electrons to the non-metal atom.

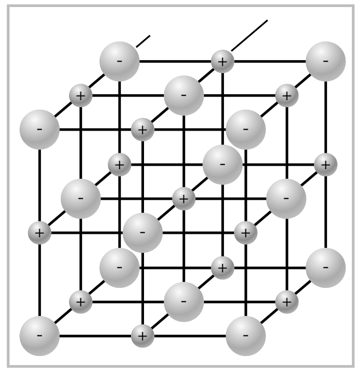




Metal atoms ____ electrons to become ____ ions.
Non-metal atoms ____ electrons to become ____ ions.

Giant ionic lattice

When metal atoms ____ electrons to non-metal atoms you end up with ____ and ____ ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called ____ ____.



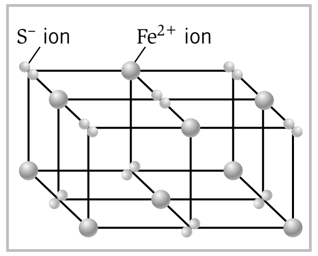
The electrostatic force of attraction works in all ____, so many billions of ions can be bonded together in a ____ structure.

Formulae

The formula of an ionic substance can be worked out

1 from its ____:
for every ____ magnesium ion there are ____ fluoride ions – so the formula for magnesium fluoride is MgF_2

2 from a ____:
there are nine Fe^{2+} ions and 18 S^- ions – simplifying this ratio gives a formula of ____



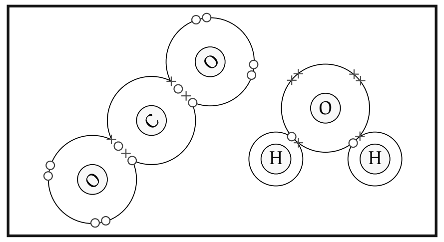
Covalent bonding

Atoms can ____ or ____ electrons to form strong chemical bonds.

A **covalent bond** is when electrons are ____ between ____ atoms.

The number of electrons shared depends on how many ____ electrons an atom needs to make a full ____.

If you include electrons that are shared between atoms, each atom has a full outer shell.
Single bond = each atom shares ____ pair of electrons.
Double bond = each atom shares ____ pairs of electrons.



Covalent structures

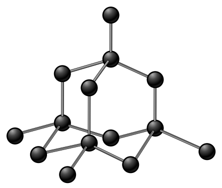
There are three main types of covalent structure:

Structure and bonding

Giant covalent

Many billions of atoms, each one with a ____ covalent bond to a number of others.

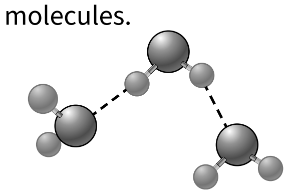
An example of a giant covalent structure is ____.



Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak ____ ____.

For example, ____ is made of small molecules.



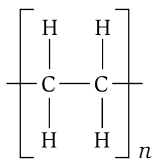
Large molecules

Many repeating units joined by covalent bonds to form a ____.

The small section is bonded to many identical sections to the left and right. The 'n' represents a ____.

Separate chains are held together by intermolecular forces that are stronger than in ____ molecules.

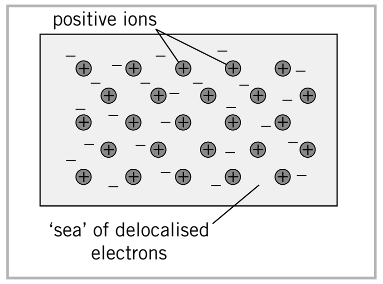
____ are examples of long molecules.



Metals: Structure and properties

The atoms that make up metals form ____. The electrons in the outer shells of the atoms are ____ – this means they are free to move through the ____ structure.

The positive metal ions are then attracted to these delocalised electrons by the ____.



Some important properties of metals are:

-
-
-

Chapter 3: Bonding 2

Knowledge organiser

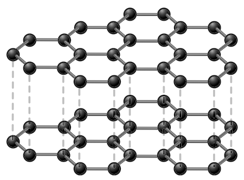
Properties			
	High melting and boiling points because the ________ covalent bonds between the atoms must be ________ to melt or boil the substances. This requires a lot of ________. ________ at room temperature.	________ melting and boiling points because only the ________ forces need to be overcome to melt or boil the substances, not the ________ between the atoms. This does not require a lot of energy as the intermolecular forces are ________. Normally ________ or ________ at room temperature.	Melting and boiling points are ________ compared to giant ________ substances but higher than for small molecules. Large molecules have ________ intermolecular forces than small molecules, which require more ________ to overcome. Normally ________ at room temperature.

Most covalent structures do not ________ electricity because they do not have ________ ________ or ________ that are free to move to carry charge.

Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

Structure



Made only of ________ – each carbon atom bonds to ________ others, and forms hexagonal rings in ________. Each carbon atom has one ________ electron, which is delocalised and therefore ________ to move around the structure.

Hardness

The layers can ________ over each other because they are not ________ bonded. Graphite is therefore softer than ________, even though both are made only of carbon, as each atom in diamond has ________ strong covalent bonds.

Conductivity

The ________ ________ electrons are free to move through graphite, so can carry charges and allow an electrical current to ________. Graphite is therefore a ________ of electricity.

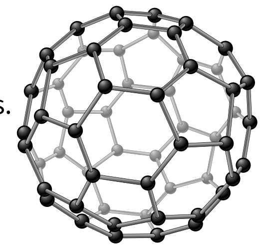
Graphene

Graphene consists of only a single layer of ________. Its strong covalent bonds make it a ________ material that can also conduct electricity. It could be used in composites and high-tech electronics.

Fullerenes

- ________ cages of carbon atoms bonded together in one molecule
- can be arranged as a ________ or a ________ (called a **nanotube**)
- molecules held together by ________ ________ forces, so can slide over each other
- conduct electricity

Spheres

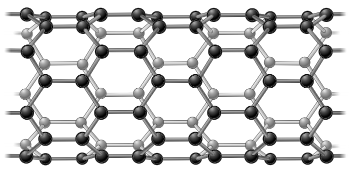


Buckminsterfullerene was the first fullerene to be discovered, and has ________ carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as ________ and in ________ ________.

Nanotubes

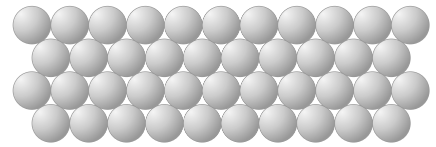


The carbon atoms in nanotubes are arranged in cylindrical tubes.
Their high ________ strength (they are difficult to break when pulled) makes them useful in electronics.

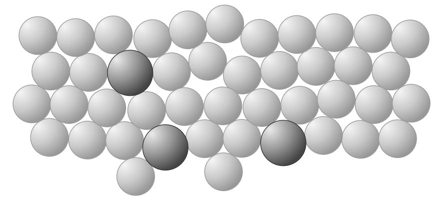
Alloys

Pure metals are often too ________ to use as they are. Adding atoms of a different element can make the resulting mixture ________ because the new atoms will be a different ________ to the pure metal's atoms. This will disturb the ________ arrangement of the layers, preventing them from ________ over each other.

The harder mixture is called an **alloy**.



pure iron



iron alloy

Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	1×10^{-4} m	0.0001 m
coarse particles (e.g., dust)	PM_{10}	10 µm	1×10^{-5} m	0.00001 m
fine particles	$PM_{2.5}$	100 nm	1×10^{-7} m	0.0000001 m
nanoparticles	$< PM_{2.5}$	1 to 100 nm	1×10^{-9} to 1×10^{-7} m	0.000000001 m to 0.0000001 m

PM stands for ________ and is another way of measuring very small particles.

Uses of nanoparticles

Nanoparticles often have very different ________ to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in ________, ________, ________, and as ________.

However, nanoparticles have the potential to be hazardous to health and to ________, so it is important that they are researched further.

Key terms

Make sure you can write a definition for these key terms.

conductivity conductor delocalised electron electrostatic force of attraction ion lattice layer malleable nanoparticle particulate matter surface area to volume ratio transfer

Chapter 3: Bonding

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	C3 questions	Answers
1	How are covalent bonds formed?	
2	Which type of atoms form covalent bonds between them?	
3	Describe the structure and bonding of a giant covalent substance.	
4	Describe the structure and bonding of small molecules.	
5	Describe the structure and bonding of polymers.	
6	Why do giant covalent substances have high melting points?	
7	Why do small molecules have low melting points?	
8	Why do large molecules have higher melting and boiling points than small molecules?	
9	Why do most covalent substances not conduct electricity?	
10	Describe the structure and bonding in graphite.	
11	Why can graphite conduct electricity?	
12	Explain why graphite is soft.	
13	What is graphene?	
14	Give two properties of graphene.	
15	What is a fullerene?	
16	What is a nanotube?	
17	Give two properties of nanotubes.	
18	Give three uses of fullerenes.	

19	What is an ion?	
20	Which kinds of elements form ionic bonds?	
21	What charges do ions from Groups 1 and 2 form?	
22	What charges do ions from Groups 6 and 7 form?	
23	Name the force that holds oppositely charged ions together.	
24	Describe the structure of a giant ionic lattice.	
25	Why do ionic substances have high melting points?	
26	Why don't ionic substances conduct electricity when solid?	
27	When can ionic substances conduct electricity?	
28	Why do ionic substances conduct electricity when melted or dissolved?	
29	Describe the structure of a pure metal.	
30	Describe the bonding in a pure metal.	
31	What are four properties of pure metals?	
32	Explain why pure metals are malleable.	
33	Explain why metals have high melting and boiling points.	
34	Why are metals good conductors of electricity and of thermal energy?	
35	What is an alloy?	
36	Explain why alloys are harder than pure metals.	
37	How big are nanoparticles?	
38	How are nanomaterials different from bulk materials?	
39	What is the relationship between side length and surface area-to-volume ratio?	
40	What are nanoparticles used for?	

Chapter 4: Calculations

Knowledge organiser

Formula mass

Every substance has a **formula mass**, M_r.

formula mass M_r = sum (relative atomic mass of all the atoms in the formula)

Avogadro's constant (HT only)

One mole of a substance contains 6.02×10^{23} atoms, ions, or molecules. This is **Avogadro's constant**.

One mole of a substance has the same mass as the M_r of the substance. For example, the M_r (H_2O) = 18, so 18 g of water molecules contains 6.02×10^{23} molecules, and is called one mole of water.

You can write this as: $\text{moles} = \dfrac{\text{mass}}{M_r}$

Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be produced.

Even though no atoms are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because

- some of the product can be lost when it is separated from the reaction mixture
- there can be unexpected side reactions between reactants that produce different products
- the reaction may be reversible.

Percentage yield

The **yield** is the amount of product that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Atom economy

The **atom economy** of a reaction tells you the proportion of atoms that you started with that are part of *useful* products.

High atom economies are more sustainable, as they mean fewer atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

$$\text{atom economy} = \frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100$$

Key terms

Make sure you can write a definition for these key terms.

atom economy, burette, concordant, end point, excess reactant, formula mass, limiting reactant, percentage yield, pipette, room temperature and pressure, theoretical yield, titration, titre, useful, yield

Using balanced equations (HT only)

In a balanced symbol equation the sum of the M_r of the reactants equals the sum of the M_r of the products.

If you are asked what mass of a product will be formed from a given mass of a specific reactant, you can use the steps below to calculate the result.

1. balance the symbol equation
2. calculate moles of the substance with a known mass using $\text{moles} = \dfrac{\text{mass}}{M_r}$
3. using the balanced symbol equation, work out the number of moles of the unknown substance
4. calculate the mass of the unknown substance using mass = moles × M_r

If you are asked to balance an equation, you can use the steps below to work out the answer.

1. work out M_r of all the substances
2. calculate the number of moles of each substance in the reaction using $\text{moles} = \dfrac{\text{mass}}{M_r}$
3. convert to a whole number ratio
4. balance the symbol equation

Concentration

Concentration is the amount of solute in a volume of solvent.

The unit of concentration is g/dm^3. Concentration can be calculated using:

$$\text{concentration (g/dm}^3) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$$

Sometimes volume is measured in cm^3:

$$\text{volume (dm}^3) = \frac{\text{volume (cm}^3)}{1000}$$

- lots of solute in little solution = high concentration
- little solute in lots of solution = low concentration

Concentration in mol/dm^3

Concentration can also be measured in mol/dm^3.

$$\text{concentration of solution (mol/dm}^3) = \frac{\text{number of moles of solute}}{\text{volume of solution (dm}^3)}$$

You can use this formula and mass = moles × M_r to calculate the mass of solute dissolved in a solution.

- The greater the mass of solute in solution, the greater the number of moles of solute, and therefore the greater the concentration.
- If the same number moles of solute is dissolved in a smaller volume of solution, the concentration will be greater.

mol is a the unit of moles

Moles of gases (HT only)

At any given temperature and pressure, the same number of moles of a gas will occupy the same volume.

At room temperature (25 °C) and pressure (1 atm), one mole of *any* gas will occupy 24 dm^3.

To calculate the number of moles of a gas:

$$\text{moles of a gas} = \frac{\text{volume (dm}^3)}{24\text{ dm}^3}$$

or

$$\text{moles of a gas} = \frac{\text{volume (cm}^3)}{24\,000\text{ cm}^3}$$

Calculating concentration

To calculate the concentration of the unknown solution (the solution in the conical flask):

1. Write a balanced symbol equation for the reaction.
2. Calculate the moles used from the known solution using: $\text{moles} = \text{concentration (mol/dm}^3) \times \text{volume (dm}^3)$
3. Use the ratio from the balanced symbol equation to deduce the number of moles present in the unknown solution.
4. Calculate the concentration of the unknown solution using: $\text{concentration (mol/dm}^3) = \dfrac{\text{moles}}{\text{volume (dm}^3)}$

Excess and limiting reactants (HT only)

In a chemical reaction between two or more reactants, often one of the reactants will run out before the others. You then have some of the other reactants left over. The reactant that is left over is in **excess**. The reactant that runs out is the **limiting reactant**.

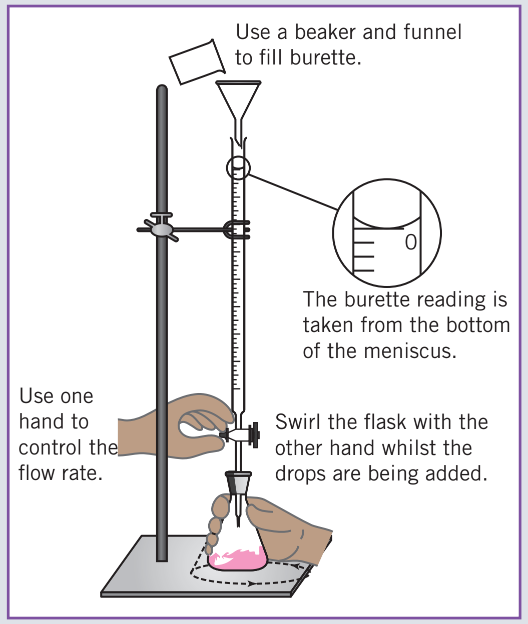
To work out which reactants are in excess and which is the limiting reactant, you need to:

1. write the balanced symbol equation for the reaction
2. pick one of the reactants and its quantity as given in the question
3. use the ratio of the reactants in the balanced equation to see how much of the other reactant you need
4. compare this value to the quantity given in the question
5. determine which reactant is in excess and which is limiting.

Titration

Titration is an experimental technique to work out the concentration of an unknown solution in the reaction between an acid and an alkali.

1. Use a pipette to extract a known volume of the solution with an unknown concentration. A pipette measures a fixed volume only.
2. Add the solution of unknown concentration to a conical flask and put the conical flask on a white tile.
3. Add a few drops of a suitable indicator to the conical flask.
4. Add the other solution with a known concentration to the burette.
5. Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm^3 at a time until the end point is reached.
6. The end point is when the indicator just changes colour.
7. Record the volume of the end point as your rough value.
8. Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. Swirl the conical flask in between drops.
9. Record the volume of the end point.



Chapter 4: Calculations

Knowledge organiser

Formula mass

Every substance has a ____________, M_r.

M_r = ____

Avogadro's constant (HT only)

One mole of a substance contains ________ atoms, ions, or molecules. This is **Avogadro's constant**.

One mole of a substance has the same _______ as the M_r of the substance. For example, the M_r (H_2O) = _____, so _____g of water molecules contains ________ molecules, and is called one ________ of water.

You can write this as: moles = ________

Using balanced equations (HT only)

In a balanced symbol equation the sum of the M_r of the reactants equals the sum of the M_r of the products.

Write down the steps for how to calculate the mass of a product from a given mass of a specific reactant.

1. ______________________________
2. ______________________________
____
3. ______________________________
____
4. ______________________________

Write down the steps for how to balance an equation.

1. ______________________________
2. ______________________________
____
3. ______________________________
4. ______________________________

Excess and limiting reactants (HT only)

In a chemical reaction between two or more reactants, often one of the reactants will run out before the others. You then have some of the other reactants left over. The reactant that is left over is in ________. The reactant that runs out is the ______________ ______________.

Write down the steps for working out which reactants are in excess, and which is the limiting reactant.

1. ______________________________
2. ______________________________
____
3. ______________________________
____
4. ______________________________
5. ______________________________

Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be ________.

Even though no ______ are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because:

-
-
-

Percentage yield

The **yield** is the amount of ________ that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

percentage yield =

Atom economy

The **atom economy** of a reaction tells you the __________ of atoms that you started with that are part of ________ products.

High atom economies are more sustainable, as they mean ________ atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

atom economy =

Concentration

Concentration is the amount of solute in a ________ of solvent.

The unit of concentration is g/dm³. Concentration can be calculated using:

concentration (g/dm³) =

Sometimes volume is measured in cm³:

volume (dm³) = ____________

- lots of solute in little solution = ________ ______________
- little solute in lots of solution = ________ ______________

Concentration in mol/dm³

Concentration can also be measured in mol/dm³.

concentration of solution (mol/dm³) =

You can use this formula and mass = moles × M_r to calculate ____________ ______________.

- The greater the mass of solute in solution, the greater the number of ________ of solute, and therefore the greater the ______________.
- If the _____ number moles of solute is dissolved in a smaller volume of solution, the concentration will be _____.

mol is a the unit of moles

Moles of gases (HT only)

At any given temperature and pressure, the same number of moles of a gas will ________ the same volume.

At room temperature (________) and pressure (________), one mole of *any* gas will occupy ________.

To calculate the number of moles of a gas:

$$\text{moles of a gas} = \frac{\_\_\_\_\_\_}{24\ \text{dm}^3}$$

or

$$\text{moles of a gas} = \frac{\_\_\_\_\_\_}{\text{cm}^3}$$

Calculating concentration

To calculate the concentration of the unknown solution (the solution in the conical flask):

1. Write a ____________________ for the reaction.
2. Calculate the moles used from the known solution using:

moles =

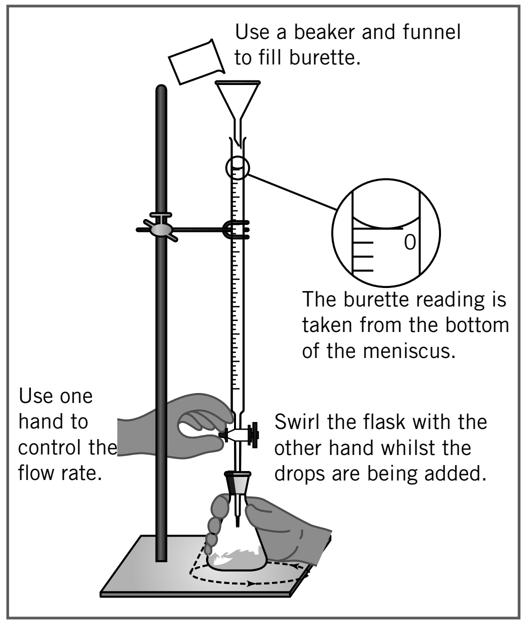
3. Use the ________ from the balanced symbol equation to deduce the number of moles present in the unknown solution.
4. Calculate the concentration of the unknown solution using:

concentration (mol/dm³) =

Titration

Titration is an experimental technique to work out the concentration of an ________ solution in the reaction between an ________ and an ________.

1. Use a ________ to extract a known volume of the solution with an unknown concentration. A pipette measures a ________ volume only.
2. Add the solution of unknown concentration to a ________ flask and put the conical flask on a white tile.
3. Add a few ________ of a suitable indicator to the conical flask.
4. Add the other solution with a known concentration to the ________.
5. Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm³ at a time until the ________ is reached.
6. The ________ is when the indicator just changes ________.
7. Record the ________ of the end point as your rough value.
8. Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. ________ the conical flask in between drops.
9. Record the volume of the end point.



Key terms

Make sure you can write a definition for these key terms.

atom economy, burette, concordant, end point, excess reactant, formula mass, limiting reactant, percentage yield, pipette, room temperature and pressure, theoretical yield, titration, titre, useful, yield

Chapter 4: Calculations
Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	C4 questions	Answers
1	What is a mole?	
2	Give the value for Avogadro's constant.	
3	Which formula is used to calculate the number of moles from mass and M_r?	
4	Which formula is used to calculate the mass of a substance from number of moles and M_r?	
5	What is a limiting reactant?	
6	What is a unit for concentration?	
7	Which formula is used to calculate concentration from mass and volume?	
8	Which formula is used to calculate volume from concentration and mass?	
9	Which formula is used to calculate mass from concentration in g/dm^3 and volume?	
10	How can you convert a volume reading in cm^3 to dm^3?	
11	If the amount of solute in a solution is increased, what happens to its concentration?	
12	If the volume of water in a solution is increased, what happens to its concentration?	
13	What is the yield of a reaction?	
14	What is the theoretical yield of a reaction?	
15	Why is the actual yield always less than the theoretical yield?	• • •
16	What is the percentage yield?	
17	How is percentage yield calculated?	
18	What is atom economy?	
19	Why is a high atom economy desirable?	
20	How is percentage atom economy calculated?	
21	How can concentration in mol/dm^3 be calculated?	
22	What is a titration?	
23	What is the end-point?	
24	How should solution be added from the burette close to the end point?	
25	Why is a white tile used in titration?	
26	What is a titre?	
27	What volume does one mole of any gas occupy at room temperature and pressure?	

Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The **reactivity** of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have *high* reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have *low* reactivity.

Reactivity series

The reactivity series places metals in order of their reactivity.

Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are non-metals.

Reaction with water	Reaction with acid	Reactivity series: Metal	Reactivity series: Reactivity	Extraction method
fizzes, gives off hydrogen gas	explodes	potassium	high reactivity	electrolysis
fizzes, gives off hydrogen gas	explodes	sodium	Decreasing reactivity	electrolysis
fizzes, gives off hydrogen gas	explodes	lithium	Decreasing reactivity	electrolysis
fizzes, gives off hydrogen gas	fizzes, gives off hydrogen gas	calcium	Decreasing reactivity	electrolysis
reacts very slowly	fizzes, gives off hydrogen gas	magnesium	Decreasing reactivity	electrolysis
reacts very slowly	fizzes, gives off hydrogen gas	aluminium	Decreasing reactivity	electrolysis
reacts very slowly	fizzes, gives off hydrogen gas	(carbon)	Decreasing reactivity	
reacts very slowly	fizzes, gives off hydrogen gas	zinc	Decreasing reactivity	reduction with carbon
reacts very slowly	fizzes, gives off hydrogen gas	iron	Decreasing reactivity	reduction with carbon
no reaction	reacts slowly with warm acid	tin	Decreasing reactivity	reduction with carbon
no reaction	reacts slowly with warm acid	lead	Decreasing reactivity	reduction with carbon
no reaction	no reaction	(hydrogen)	Decreasing reactivity	
no reaction	no reaction	copper	Decreasing reactivity	reduction with carbon
no reaction	no reaction	silver	Decreasing reactivity	mined from the Earth's crust
no reaction	no reaction	gold	low reactivity	mined from the Earth's crust

Metal extraction

Some metals, like gold, are so unreactive that they are found as pure metals in the Earth's crust and can be mined.

Most metals exist as compounds in rock and have to be extracted from the rock. If there is enough metal compound in the rock to be worth extracting it is called an **ore**.

Metals that are less reactive than carbon can be extracted by reduction with carbon. For example:

iron oxide + carbon → iron + carbon dioxide

Metals that are more reactive than carbon can be extracted using a process called **electrolysis**.

Reduction and oxidation

If a substance gains oxygen in a reaction, it has been **oxidised**.

If a substance loses oxygen in a reaction, it has been **reduced**.

For example:

iron + oxygen → iron oxide

iron has been oxidised

iron oxide + carbon → iron + carbon dioxide

iron oxide has been reduced

Salts

When acids react with metals or metal compounds, they form salts. A salt is a compound where the hydrogen from an acid has been replaced by a metal. For example nitric acid, HNO_3, reacts with sodium to form $NaNO_3$. The H in nitric acid is replaced with Na.

The table shows how to name salts.

Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula	HCl	H_2SO_4	HNO_3
Ions formed in solution	H^+ and Cl^-	$2H^+$ and SO_4^{2-}	H^+ and NO_3^-
Type of salt formed	metal chloride	metal sulfate	metal nitrate
Sodium salt example	sodium chloride, $NaCl$	sodium sulfate, Na_2SO_4	sodium nitrate, $NaNO_3$

Displacement reactions

In a **displacement** reaction a *more* reactive element takes the place of a *less* reactive element in a compound.

For example:

copper sulfate + iron → iron sulfate + copper

$$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$$

Iron is more reactive than copper, so iron displaces the copper in copper sulfate.

Reactivity and ions

A metal's reactivity depends on how readily it forms an **ion** by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with iron ions, not copper ions.

Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $CuSO_4(aq)$ can be written as $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$.

The displacement reaction of copper sulfate and iron can be written as:

$$Fe(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Fe^{2+}(aq) + SO_4^{2-}(aq) + Cu(s)$$

The SO_4^{2-} is unchanged in the reaction – it is a **spectator ion**. Spectator ions are removed from the equation to give an **ionic equation**:

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$

Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Steps for writing an ionic equation (HT only)

1. check symbol equation is balanced
2. identify all aqueous ionic compounds
3. write those compounds out as ions
4. remove spectator ions.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$

A copper ion gains two electrons to form a copper atom:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

These two equations are called **half equations** – they each show half of the ionic equation.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the loss or gain of electrons.

Oxidation is the *loss* of electrons, and reduction is the *gain* of electrons.

In the example displacement reaction:

- iron atoms have been oxidised
- copper ions have been reduced.

Acids and alkalis

Acids are compounds that, when dissolved in water, release H^+ ions. There are three main acids: sulfuric acid H_2SO_4, nitric acid HNO_3, and hydrochloric acid HCl.

Alkalis are compounds that, when dissolved in water, release OH^- ions.

The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

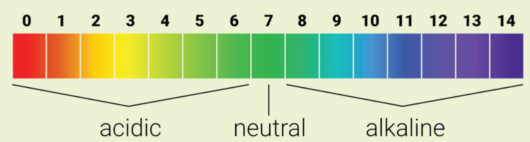
- Aqueous solutions with pH < 7 are acidic.
- Aqueous solutions with pH > 7 are alkaline.
- Aqueous solutions with pH = 7 are neutral.

Indicators

Indicators can show if something is an acid or an alkali.

- **Universal indicator** can also tell us the approximate pH of a solution.
- Electronic pH probes can give us the exact pH of a solution.

The pH scale



Reactions of acids

Reactions of acids with metals

Acids react with some metals to form salts and hydrogen gas.

magnesium + hydrochloric acid → sodium chloride + hydrogen

Neutralisation reactions

Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form salts and water.

hydrochloric acid + sodium hydroxide → sodium chloride + water

The ionic equation for this reaction is always:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Reactions of acids with metal oxides

Acids react with metal oxides to form salts and water.

hydrochloric acid + sodium oxide → sodium chloride + water

Reactions of acids with metal carbonates

Acids react with metal carbonates to form a salt, water, and carbon dioxide.

hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide

Alkalis and bases

Bases neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form alkaline solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in water. They are **bases**, but are not alkalis.

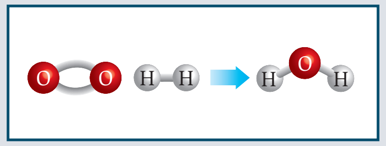
Balancing symbol equations

When writing symbol equations you need to ensure that the number of each atom on each side is equal.

$$H_2 + O_2 \rightarrow H_2O$$

unbalanced

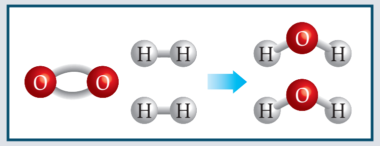
there are 2 hydrogen atoms on each side, but 2 oxygen atoms in the reactants and 1 in the product



$$2H_2 + O_2 \rightarrow 2H_2O$$

balanced

there are 4 hydrogen atoms on each side, and 2 oxygen atoms on each side



State symbols

A balanced symbol equation should also include state symbols.

State	Symbol
solid	(s)
liquid	(l)
gas	(g)
aqueous or dissolved in water	(aq)

Key terms

Make sure you can write a definition for these key terms.

displacement · electrolysis · extraction · half equation · ion · ionic equation · metal · ore · oxidation · reactivity · reactivity series · redox · reduction · spectator ion · state symbols

Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all **strong acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

- $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
- $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
- $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

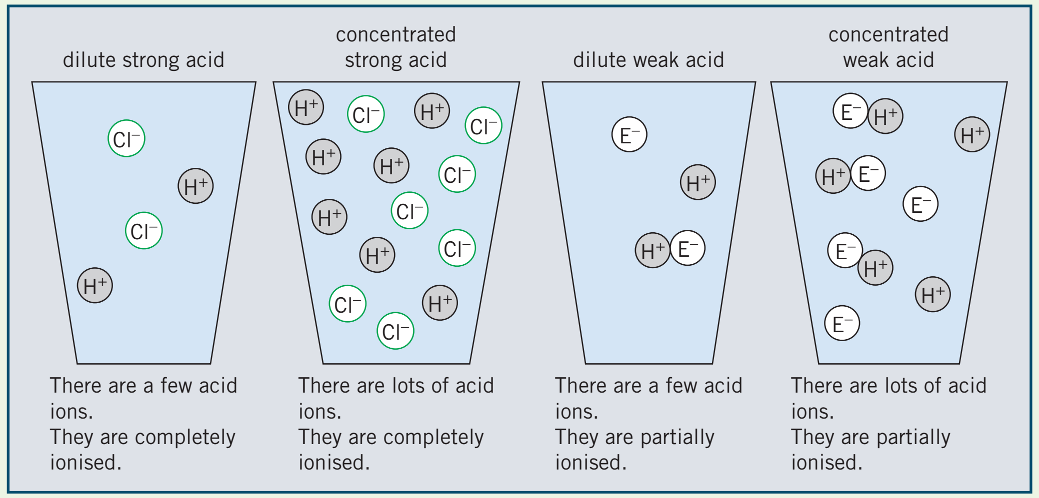
Ethanoic acid, citric acid, and carbonic acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are partially ionised.

For a given concentration, the *stronger* the acid, the *lower* the pH.

Concentrated and dilute acids

Concentration tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a small volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.

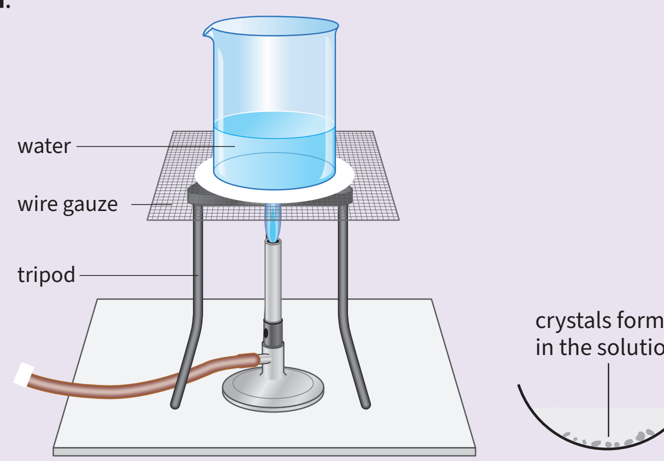


Crystallisation

You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

1. Choose the correct acid and base to produce the salt.
2. Put some of the dilute acid into a flask. Heat gently with a Bunsen burner.
3. Add a small amount of the base and stir.
4. Keep adding the base until no more reacts – the base is now in excess.
5. Filter to remove the unreacted base.
6. Add the remaining solution to an evaporating dish.
7. Use a water bath or electric heater to evaporate the water. The salt crystals will be left behind.



Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The ______ of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have ______ reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have ______ reactivity.

Reactivity series

The reactivity series places ______ in order of their reactivity.

Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are ______.

Reaction with water	Reaction with acid	Reactivity series: Metal	Reactivity series: Reactivity	Extraction method
		potassium	high reactivity	
		sodium		
		lithium		
		calcium		
		magnesium		
		aluminium (carbon) zinc	Decreasing reactivity	
		iron		
		tin		
		lead (hydrogen) copper		
		silver		
		gold	low reactivity	

Metal extraction

Some metals, like gold, are so ______ that they are found as pure metals in the Earth's ______ and can be mined.

Most metals exist as compounds in rock and have to be ______ from the rock. If there is enough metal compound in the rock to be worth extracting it is called an ______.

Metals that are ______ reactive than carbon can be extracted by ______ with carbon. For example:

iron oxide + carbon ➞ ______ + ______

Metals that are more reactive than carbon can be extracted using a process called ______.

Reduction and oxidation

If a substance gains oxygen in a reaction, it has been ______.

If a substance loses oxygen in a reaction, it has been ______.

For example:

iron + oxygen ➞ iron oxide

iron has been ______

______ + carbon ➞ iron + carbon dioxide

______ has been reduced

Salts

When acids react with metals or metal compounds, they form ______. A salt is a compound where the ______ from an acid has been replaced by a metal. For example nitric acid, HNO_3, reacts with sodium to form ______. The H in nitric acid is replaced with Na.

The table shows how to name salts.

Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula			
Ions formed in solution			
Type of salt formed			
Sodium salt example			

Displacement reactions

In a **displacement** reaction a ______ reactive element takes the place of a *less* reactive element in a compound.

For example:

copper sulfate + iron ➞ ______ + ______

$\_\_\_\__4$(aq) + ____(s) ➞ ____(aq) + ____(s)

______ is more reactive than copper, so iron displaces the copper in copper sulfate.

Reactivity and ions

A metal's reactivity depends on how readily it forms an ______ by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with ______ ions, not ______ ions.

Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $CuSO_4$(aq) can be written as ______ and ______.

The displacement reaction of copper sulfate and iron can be written as:

____

The SO_4^{2-} is unchanged in the reaction – it is a ______ ______. Spectator ions are removed from the equation to give an **ionic equation**:

____

Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Steps for writing an ionic equation (HT only)

1.
2.
3.
4.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the ______ or ______ of electrons.

Oxidation is the ______ of electrons, and reduction is the ______ of electrons.

In the example displacement reaction:

- iron atoms have been ______
- copper ions have been ______.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:

Fe(s) ➞ ______ + ______

A copper ion gains two electrons to form a copper atom:

______ + ______ ➞ Cu(s)

These two equations are called ______ – they each show half of the ionic equation.

Acids and alkalis

Acids are compounds that, when dissolved in water, release ____ ions. There are three main acids: ______ ______, ______ ______, and ______ ______.

Alkalis are compounds that, when dissolved in water, release ______ ions.

The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

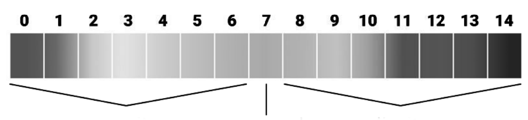
- Aqueous solutions with pH < 7 are ______.
- Aqueous solutions with pH > 7 are ______.
- Aqueous solutions with pH = 7 are ______.

Indicators

Indicators can show if something is an acid or an alkali.

- ______ ______ can also tell us the approximate pH of a solution.
- ______ ______ ______ can give us the exact pH of a solution.

The pH scale



______ ______ ______

Chapter 5: Chemical changes 2

Knowledge organiser

Reactions of acids

Reactions of acids with metals

Acids react with some metals to form ______ and ______.

magnesium + hydrochloric acid → ______

Neutralisation reactions

Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form ______ and ______.

hydrochloric acid + sodium hydroxide → ______

The ionic equation for this reaction is always:

______

Reactions of acids with metal oxides

Acids react with metal oxides to form ______ and ______.

______ + ______ → ______ + ______

Reactions of acids with metal carbonates

Acids react with metal carbonates to form a ______, ______ and ______.

hydrochloric acid + sodium carbonate → ______

______

Alkalis and bases

______ neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form ______ solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in ______. They are **bases**, but are not alkalis.

Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all ______ **acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

- ______ $(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
- $HNO_3(aq) \rightarrow$ ______ + ______
- $HCl(aq) \rightarrow H^+(aq) +$ ______

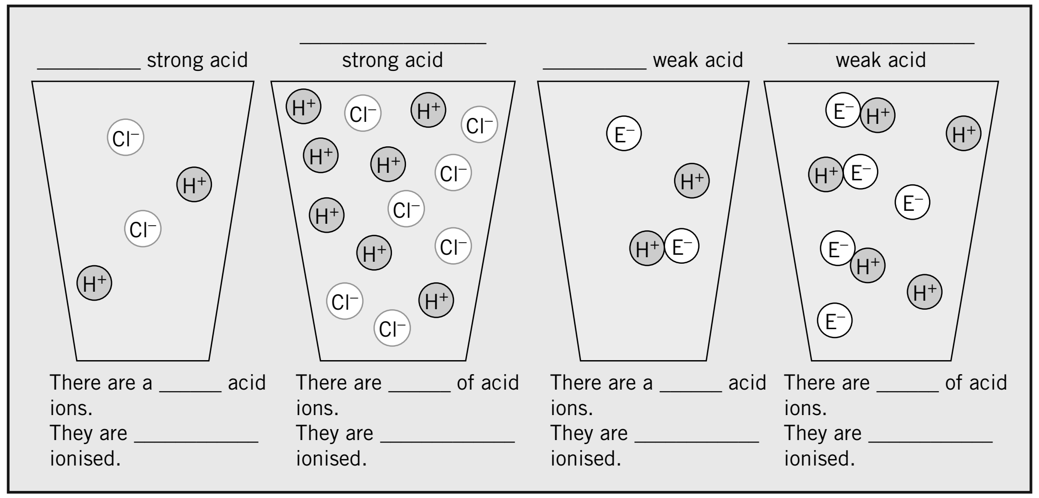
______ acid, ______ acid, and ______ acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are ______ ionised.

For a given concentration, the ______ the acid, the ______ the pH.

Concentrated and dilute acids

Concentration tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a ______ volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.



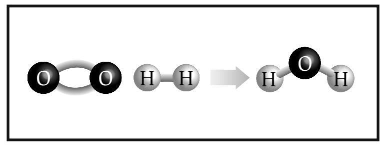
Balancing symbol equations

When writing symbol equations you need to ensure that the number of each ______ on each side is ______.

$H_2 + O_2 \rightarrow H_2O$

unbalanced

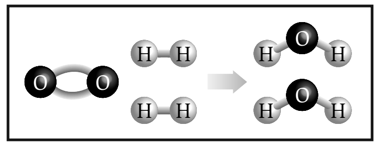
there are ___ hydrogen atoms on each side, but ___ oxygen atoms in the reactants and ___ in the product



$\_\_H_2 + O_2 \rightarrow \_\_H_2O$

balanced

there are ___ hydrogen atoms on each side, and ___ oxygen atoms on each side



State symbols

A balanced symbol equation should also include state symbols. Complete the table.

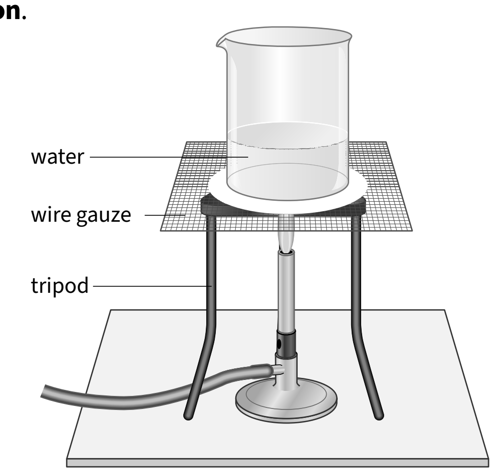
State	Symbol

Crystallisation

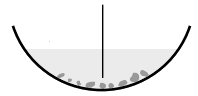
You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

1. ______
2. ______
   ______
3. ______
4. ______
   ______
5. ______
6. ______
7. ______
   ______



crystals form in the solution



Key terms

Make sure you can write a definition for these key terms.

displacement *electrolysis* *extraction* *half equation* *ion* *ionic equation* *metal* *ore* *oxidation* *reactivity* *reactivity series* *redox* *reduction* *spectator ion* *state symbols*

Chapter 5: Chemical changes

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

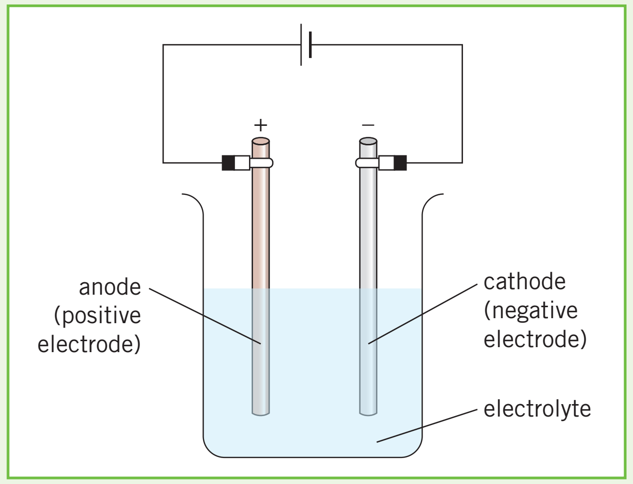
	C5 questions	Answers
1	What does reactivity mean?	
2	How can metals be ordered by their reactivity?	
3	What name is given to a list of metals ordered by their reactivity?	
4	In terms of electrons, what makes some metals more reactive than others?	
5	Why are gold and silver found naturally as elements in the Earth's crust?	
6	What is an ore?	
7	How are metals less reactive than carbon extracted from their ores?	
8	In terms of oxygen, what is oxidation?	
9	In terms of oxygen, what is reduction?	
10	Why can metals like potassium and aluminium not be extracted by reduction with carbon?	
11	How are metals more reactive than carbon extracted from their ores?	
12	What is a displacement reaction?	
13	What is an ionic equation?	
14	What type of substance is given as ions in an ionic equation?	
15	What is a spectator ion?	
16	What is a half equation?	
17	In terms of electrons, what is oxidation?	
18	In terms of electrons, what is reduction?	
19	In terms of pH, what is an acid?	
20	In terms of pH, what is a neutral solution?	
21	In terms of H^+ ions, what is an acid?	
22	How is the amount of H^+ ions in a solution related to its pH?	
23	What are the names and formulae of three main acids?	
24	How do you measure the pH of a substance?	
25	What is a strong acid?	
26	What is a weak acid?	
27	What is a salt?	
28	Which type of salts do sulfuric acid, hydrochloric acid, and nitric acid form?	
29	What are the products of a reaction between a metal and an acid?	
30	What are the products of a reaction between a metal hydroxide and an acid?	
31	What are the products of a reaction between a metal oxide and an acid?	
32	What are the products of a reaction between a metal carbonate and an acid?	
33	What is a base?	
34	What is an alkali?	
35	What is a neutralisation reaction?	
36	What is the ionic equation for a reaction between an acid and an alkali?	
37	How can you obtain a solid salt from a solution?	
38	When an acid reacts with a metal, which species is oxidised?	
39	When an acid reacts with a metal, which species is reduced?	
40	What are the four state symbols and what do they stand for?	

Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric current is passed through an **electrolyte**. An electrolyte is a liquid or solution that contains ions and so can conduct electricity. This causes the ions to move to the **electrodes**, where they form pure elements.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be molten or dissolved, so the ions are free to move.

When an ionic compound is molten:

- The positive metal ions are *attracted* to the **cathode**, where they will *gain* electrons to form the pure metal
- The negative non-metal ions are *attracted* to the **anode**, where they will *lose* electrons and become the pure non-metal.

For example, molten sodium chloride, NaCl, can undergo electrolysis to form sodium at the cathode and chlorine at the anode.

Half equations (HT only)

sodium chloride → sodium + chlorine

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

- at the cathode:

$2Na^+(l) + 2e^- \rightarrow 2Na(s)$

- at the anode:

$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

Electrolysis is used if the metal is more reactive than carbon.

Aluminium is extracted from aluminium oxide by electrolysis.

1 The aluminium oxide is mixed with a substance called **cryolite**, which lowers the melting point.
2 The mixture is then heated until it is molten.
3 The resulting molten mixture undergoes electrolysis.

aluminium oxide → aluminium + oxygen

$2Al_2O_3(l) \rightarrow 4Al(l) + 3O_2(g)$

cathode: pure aluminium is formed

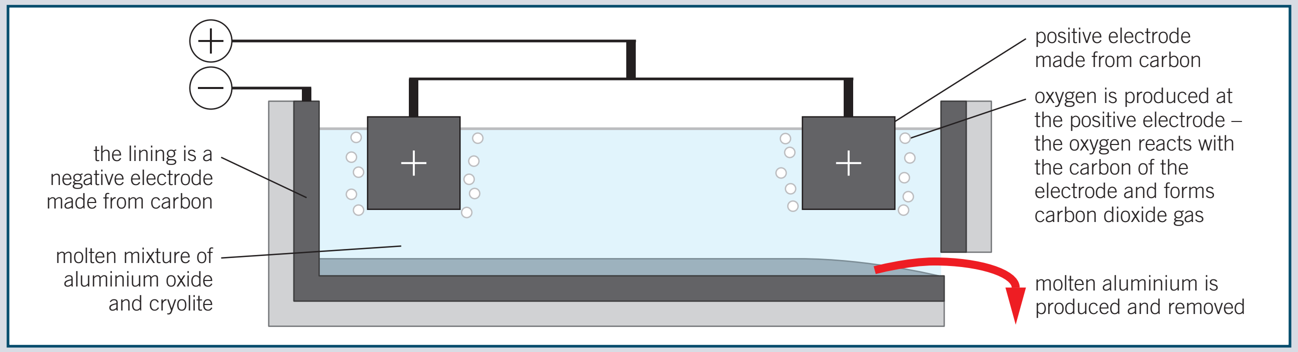
$Al^{3+}(l) + 3e^- \rightarrow Al(l)$

anode: oxygen is formed

$2O^{2-}(l) \rightarrow O_2(g) + 4e^-$

In the electrolysis of aluminium, the anode is made of graphite.

The graphite reacts with the oxygen to form carbon dioxide and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires less energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo ionisation:

$$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$$

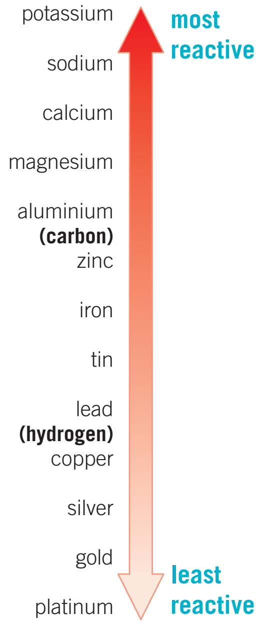
Products at the anode

In In the electrolysis of a solution, if the non-metal contains oxygen then oxygen gas is formed at the anode:

- The $OH^-(aq)$ ions formed from the ionisation of water are attracted to the anode.
- The $OH^-(aq)$ ions lose electrons to the anode and form oxygen gas.
- $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$



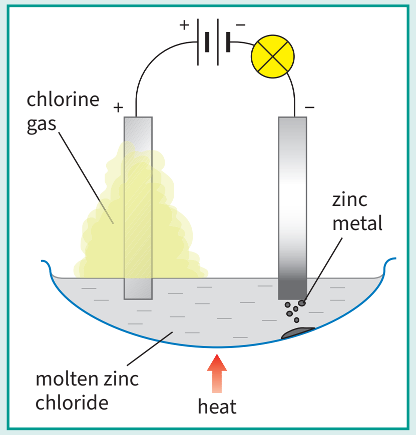
Products at the cathode

In the electrolysis of a solution, if the metal is *more* **reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The $H^+(aq)$ ions from the ionisation of water are attracted to the cathode and react with it.
- The $H^+(aq)$ ions gain electrons from the cathode and form hydrogen gas.
- $2H^+(aq) + 2e^- \rightarrow H_2(g)$
- The metal ions remain in solution.

Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means zinc metal is collected at the cathode and a pale green chlorine gas is collected at the anode. Free ions from the molten zinc chloride are able to move around and carry electric currents, hence why the bulb lights up.



Key terms

Make sure you can write a definition for these key terms.

anode · cathode · cryolite · electrode · electrolysis · electrolyte · reactivity

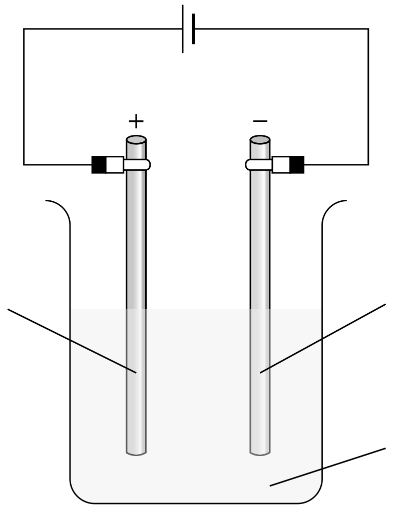
Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric ________ is passed through an **electrolyte**. An electrolyte is a ________________ that contains ________ and so can conduct electricity. This causes the ions to move to the ________, where they form pure elements.

Label the diagram.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be ________ or dissolved, so the ions are free to move.

When an ionic compound is molten:

- The positive metal ions are *attracted* to the ________, where they will ________ electrons to form the pure metal
- The negative non-metal ions are *attracted* to the ________, where they will ________ electrons and become the pure non-metal.

For example, molten sodium chloride, NaCl, can undergo electrolysis to form ________ at the cathode and ________ at the anode.

Half equations (HT only)

sodium chloride → sodium + chlorine

________ ________ → ________ + ________

- at the cathode:

________ + ________ → ________

- at the anode:

________ → ________ + ________

Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

Electrolysis is used if the metal is more reactive than ________.

Aluminium is extracted from ________ ________ by electrolysis.

1 The aluminium oxide is mixed with a substance called ________, which lowers the melting point.
2 The mixture is then heated until it is ________.
3 The resulting molten mixture undergoes electrolysis.

aluminium oxide → aluminium + oxygen

$2Al_2O_3(l)$ → ________ + ________

cathode: pure aluminium is formed

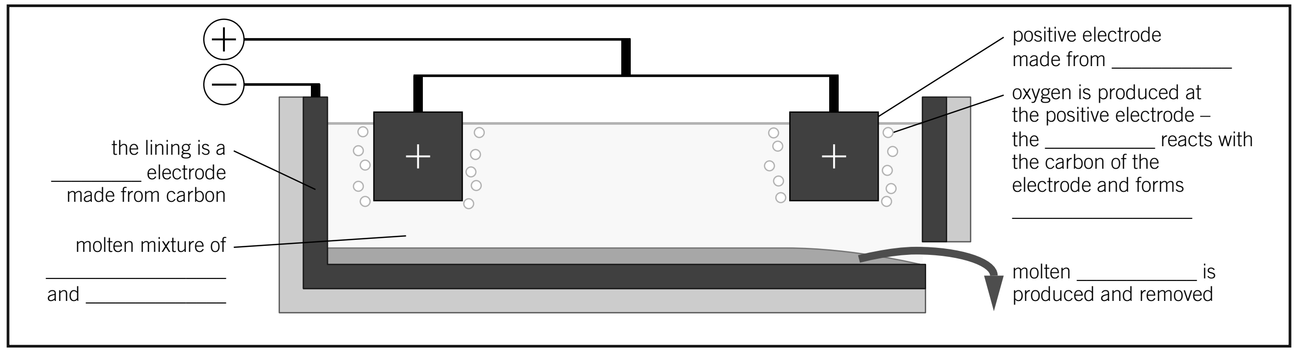
________ + ________ → ________

anode: oxygen is formed

________ → $O_2(g) + 4e^-$

In the electrolysis of aluminium, the anode is made of ________.

The graphite reacts with the ________ to form ________ and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires ________ energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo ________:

$$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$$

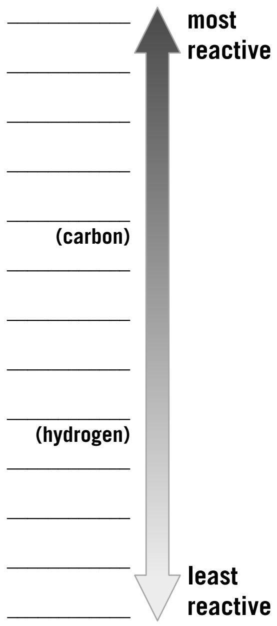
Products at the anode

In In the electrolysis of a solution, if the non-metal contains oxygen then oxygen ________ is formed at the anode:

- The ________ ions formed from the ionisation of water are attracted to the anode.
- The $OH^-(aq)$ ions ________ electrons to the anode and form oxygen gas.
- $4OH^-(aq)$ → ________

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2Cl^-(aq)$ → ________



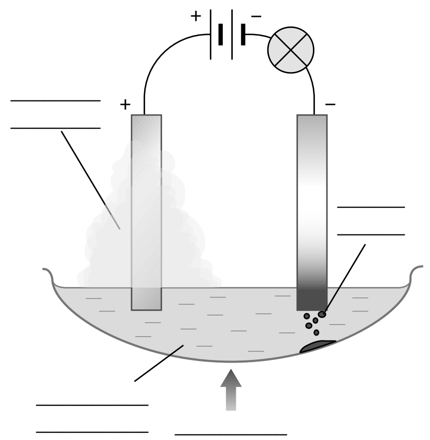
Products at the cathode

In the electrolysis of a solution, if the metal is ________ **reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The ________ ions from the ionisation of water are attracted to the cathode and react with it.
- The $H^+(aq)$ ions ________ electrons from the cathode and form hydrogen gas.
- $2H^+(aq)$ + ________
- The metal ions remain in ________.

Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means ________ metal is collected at the ________ and a ________ is collected at the ________. Free ________ from the molten zinc chloride are able to move around and carry ________, hence why the bulb lights up. Label the diagram.



Key terms Make sure you can write a definition for these key terms.

anode cathode cryolite electrode electrolysis electrolyte reactivity

Chapter 6: Electrolysis

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	C6 questions	Answers
1	What is electrolysis?	
2	What is the name of the positive electrode?	
3	What is the name of the negative electrode?	
4	What is an electrolyte?	
5	Where are metals formed?	
6	Where are non-metals formed?	
7	How can ionic substances be electrolysed?	
8	Why can solid ionic substances not be electrolysed?	
9	In the electrolysis of solutions, when is the metal *not* produced at the cathode?	
10	In the electrolysis of a metal halide solution, what is produced at the anode?	
11	In the electrolysis of a metal sulfate solution, what is produced at the anode?	
12	What is the half equation for the ionisation of water?	
13	What metals are extracted from ionic compounds by using electrolysis?	
14	In the electrolysis of aluminium oxide, why is the aluminium oxide mixed with cryolite?	
15	In the electrolysis of aluminium oxide, what are the anodes made of?	
16	In the electrolysis of aluminium oxide, why do the anodes need to be replaced?	

Chapter 7: Energy changes

Knowledge organiser

Energy changes

During a chemical reaction, energy transfers occur.

Energy can be transferred:

- to the surroundings – **exothermic**
- from the surroundings – **endothermic**

This energy transfer can cause a temperature change.

Energy is always conserved in chemical reactions.

This means that there is the same amount of energy in the Universe at the start of a chemical reaction as at the end of the chemical reaction.

The surroundings

When chemists say energy is transferred from or to "the *surroundings*" they mean "everything that isn't the reaction".

For example, imagine you have a reaction mixture in a test tube. If you measure the temperature in the test tube using a thermometer, the thermometer is then part of the surroundings.

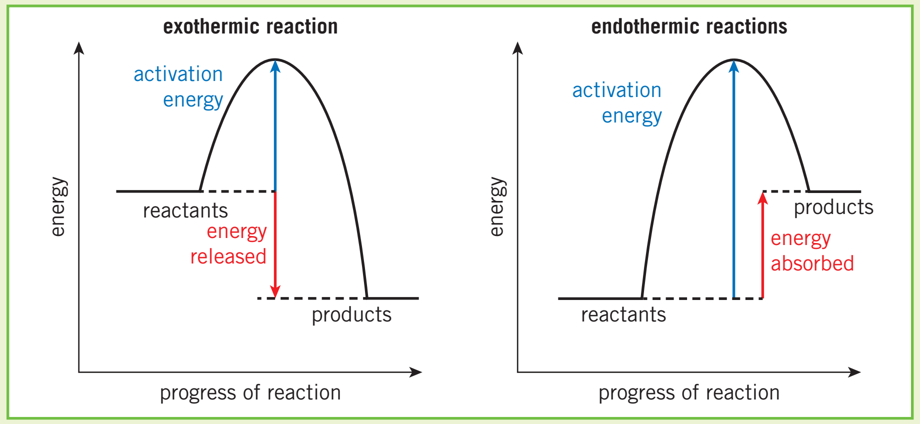
- If the thermometer records an increase in temperature, the reaction in the test tube is exothermic.
- If the thermometer records a decrease in temperature, the reaction in the test tube is endothermic.

Reaction	Energy transfer	Temperature change	Example	Everyday use	Bonds
exothermic	to the surroundings	temperature of the surroundings increases	• **oxidation** • **combustion** • **neutralisation**	• self-heating cans • hand warmers	more energy released when making bonds than required to break bonds
endothermic	from the surroundings	temperature of the surroundings decreases	• **thermal decomposition** • citric acid and sodium hydrogen carbonate	• sports injury packs	less energy released when making bonds than required to break bonds

Reaction profiles

A **reaction profile** shows whether a reaction is exothermic or endothermic.

The **activation energy** is the minimum amount of energy that particles must have to react when they collide.



Bonds (HT only)

Atoms are held together by strong chemical bonds. In a reaction, those bonds are broken and new ones are made between different atoms.

- Breaking a bond requires energy so is endothermic.
- Making a bond releases energy so is exothermic.

Breaking bonds

If a lot of energy is released when making the bonds and only a little energy is required to break them, then overall energy is released and the reaction as a whole is exothermic.

Making bonds

If a little energy is released when making the bonds and a lot is required to break them, then overall energy is taken in and the reaction as a whole is endothermic.

Bond calculations

Different bonds require different amounts of energy to be broken (their **bond energies**). To work out the overall energy change of a reaction, you need to:

1 work out how much energy is required to break all the bonds in the reactants

2 work out how much energy is released when making all the bonds in the products.

overall energy transferred = energy required to break bonds – energy required to make bonds

- A positive number means an endothermic reaction.
- A negative number means an exothermic number.

Chemical cells

In a metal displacement reaction, one metal is oxidised – it loses electrons. These electrons are transferred to another metal, which gains the electrons and so is reduced.

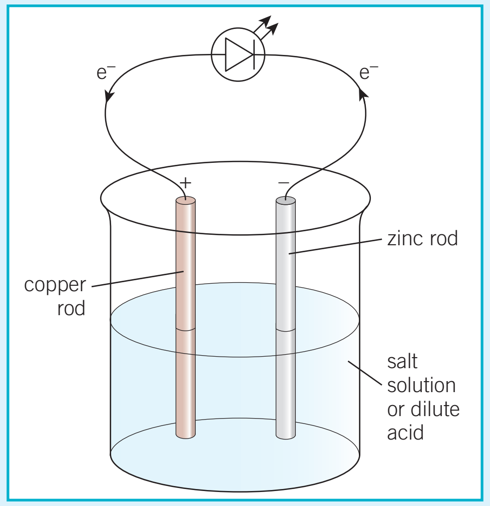
By using a **chemical cell** to conduct this reaction, the electron's movement generates a current.

In the cell shown, the zinc atoms from the electrode lose electrons, turn into ions, and move into the solution.

The electrons travel through the circuit to the copper electrode, causing the LED to light up.

Once at the copper electrode, a metal ion *from the solution* will pick the electrons up and become a metal atom.

The greater the difference in reactivity between the two metals in the cell, the greater the potential difference produced.



Batteries

A **battery** is formed of two or more cells connected in series.

- Some batteries are **rechargeable**. An external electric current is applied, which reverses the reaction.
- Some batteries, like alkaline batteries, are not rechargeable because the reaction is not reversible. Once the reactants are used up, the chemical reaction stops and no more potential differences are released.

Hydrogen fuel cells

Fuel cells use a fuel and oxygen from the air to generate a potential difference.

Hydrogen fuel cells generate electricity from hydrogen and oxygen. The overall reaction is:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

The hydrogen is oxidised to produce water.

There are different types of hydrogen fuel cell. In alkaline fuel cells, the half equations are below:

- $2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$
- $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

Advantages

- the only waste is water
- do not need to be electrically recharged

Disadvantages

- hydrogen is highly flammable and difficult to store
- hydrogen is often produced from non-renewable resources

Key terms

Make sure you can write a definition for these key terms.

activation energy, battery, bond energy, chemical cell, combustion, endothermic, exothermic, fuel cell, neutralisation, oxidation, reaction profile, rechargeable, thermal decomposition

Chapter 7: Energy changes

Knowledge organiser

Energy changes

During a chemical reaction, energy transfers occur.

Energy can be transferred:

- to the surroundings – ________
- from the surroundings – ________

This energy transfer can cause a ____________ change.

Energy is always conserved in chemical reactions.

This means that there is the ____________ ________________________ ________________________

The surroundings

When chemists say energy is transferred from or to "the *surroundings*" they mean ________________.

For example, imagine you have a reaction mixture in a test tube. If you measure the temperature in the test tube using a thermometer, the thermometer is then part of the surroundings.

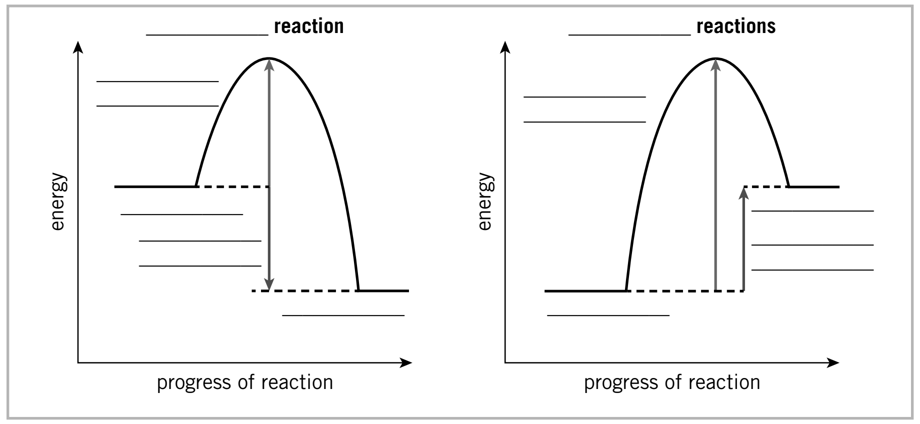
- If the thermometer records an increase in temperature, the reaction in the test tube is ____________.
- If the thermometer records a decrease in temperature, the reaction in the test tube is ____________.

Reaction	Energy transfer	Temperature change	Example	Everyday use	Bonds
exothermic			• • •	• •	
endothermic			• •	•	

Reaction profiles

A ________ ________ shows whether a reaction is exothermic or endothermic.

The ________ ________ is the minimum amount of energy that particles must have to react when they ________.



Bonds (HT only)

Atoms are held together by strong ________ bonds. In a reaction, those bonds are ________ and new ones are made between ________ atoms.

- Breaking a bond ________ energy so is ________.
- Making a bond ________ energy so is ________.

Breaking bonds

If a lot of energy is released when ________ the bonds and only a ________ energy is required to break them, then overall energy is released and the reaction as a whole is ________.

Making bonds

If a ________ energy is released when making the bonds and a ________ is required to break them, then overall energy is taken in and the reaction as a whole is ________.

Bond calculations

Different bonds require different amounts of energy to be broken (their **bond energies**). To work out the overall energy change of a reaction, you need to:

1 work out how much energy is required to break all the bonds in the ________

2 work out how much energy is ________ when making all the bonds in the products.

overall energy transferred = ________________ – ________________

- A ________ number means an endothermic reaction.
- A ________ number means an exothermic number.

Chemical cells

In a metal displacement reaction, one metal is ____________. These electrons are ____________ to another metal, which gains the electrons and so is ____________.

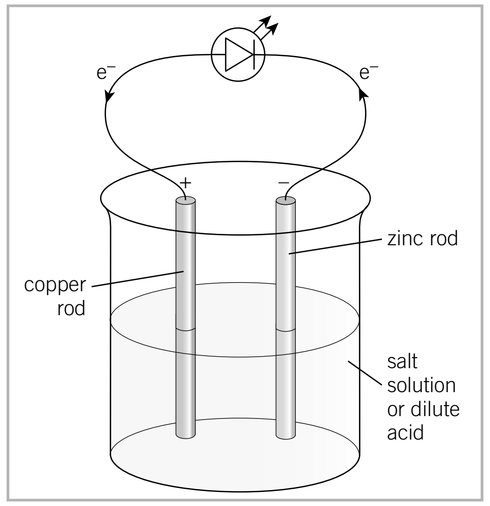
By using a **chemical cell** to conduct this reaction, the electron's movement generates a ________.

In the cell shown, the zinc atoms from the electrode lose electrons, turn into ______, and move into the solution.

The ________ travel through the circuit to the ________ electrode, causing the LED to ________.

Once at the copper electrode, a metal ion *from the solution* will pick the electrons up and become a ______ atom.

The greater the difference in reactivity between the two metals in the cell, the greater the ______ ________ produced.



Batteries

A **battery** is formed of ____________ cells connected in ______.

- Some batteries are ____________. An external electric current is applied, which reverses the reaction.
- Some batteries, like ______ batteries, are not rechargeable because the reaction is not ________. Once the reactants are used up, the chemical reaction ______ and no more potential differences are ______.

Hydrogen fuel cells

Fuel cells use a ________ and ________ from the air to generate a potential difference.

________ fuel cells generate electricity from hydrogen and oxygen. The overall reaction is:

$$2H_2(g) + O_2(g) \rightarrow \text{________}$$

The hydrogen is oxidised to produce ________.

There are different types of hydrogen fuel cell. In alkaline fuel cells, the half equations are below:

- $2H_2(g) + 4OH^-(aq) \rightarrow$ ________ + ________
- ________ + ________ + $4e^- \rightarrow 4OH^-(aq)$

Advantages

-
-

Disadvantages

-
-

Key terms

Make sure you can write a definition for these key terms.

activation energy, *battery*, *bond energy*, *chemical cell*, *combustion*, *endothermic*, *exothermic*, *fuel cell*, *neutralisation*, *oxidation*, *reaction profile*, *rechargeable*, *thermal decomposition*

Chapter 7: Energy changes

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

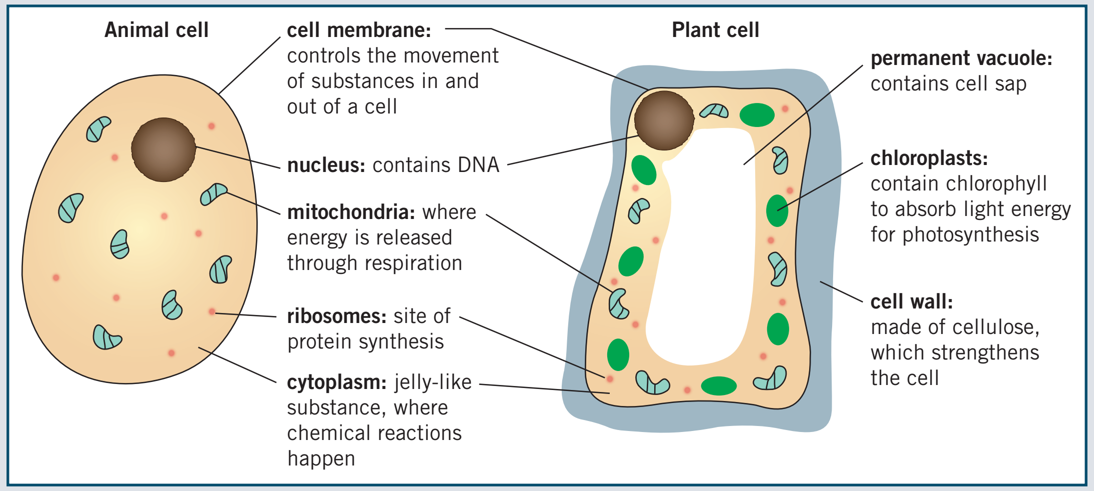
	C7 questions	Answers
1	What is an exothermic energy transfer?	
2	What is an endothermic energy transfer?	
3	What is a reaction profile?	
4	What is the activation energy?	
5	What is bond energy?	
6	In terms of bond breaking and making, what is an exothermic reaction?	
7	In terms of bond breaking and making, what is an endothermic reaction?	
8	How are chemical cells made?	
9	What is a battery?	
10	How does the potential difference of a cell depend on the metals that the electrodes are made of?	
11	How can some cells be recharged?	
12	Why can some cells not be recharged?	
13	What is a fuel cell?	
14	In the hydrogen fuel cell, what is the overall reaction?	
15	In the alkaline hydrogen fuel cells, what are the half equations?	
16	Give an advantage of the hydrogen fuel cell.	
17	Give a disadvantage of the hydrogen fuel cell.	

Chapter 1: Cell biology and transport

Knowledge organiser

Eukaryotic cells

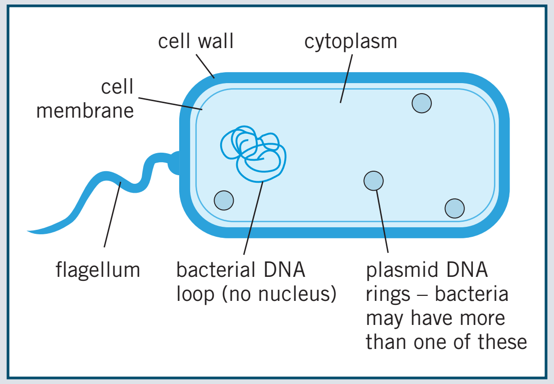
Animal and plant cells are eukaryotic. They have genetic material (DNA) that forms **chromosomes** and is contained in a **nucleus**.



Prokaryotic cells

Bacteria have the following characteristics:

- single-celled
- no nucleus – have a single loop of DNA
- have small rings of DNA called **plasmids**
- smaller than eukaryotic cells.



Microscopes

Light microscope	Electron microscope
uses light to form images	uses a beam of electrons to form images
living samples can be viewed	samples cannot be living
relatively cheap	expensive
low magnification	high magnification
low resolution	high resolution

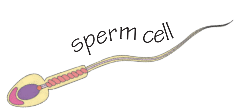
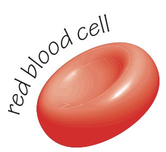
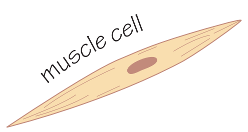
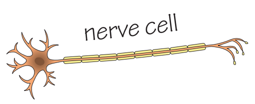
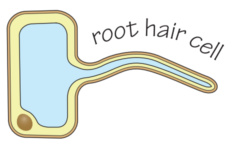
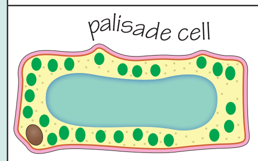
Electron microscopes allow you to see sub-cellular structures, such as ribosomes, that are too small to be seen with a light microscope.

L To calculate the **magnification** of an image:

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$

Specialised cells

Cells in animals and plants differentiate to form different types of cells. Most animal cells differentiate at an early stage of development, whereas a plant's cells differentiate throughout its lifetime.

Specialised cell	Function	Adaptations
	fertilise an ovum (egg)	• tail to swim to the ovum and fertilise it • lots of mitochondria to release energy from respiration, enabling the sperm to swim to the ovum
	transport oxygen around the body	• no nucleus so more room to carry oxygen • contains a red pigment called haemoglobin that binds to oxygen molecules • flat bi-concave disc shape to increase surface area-to- volume ratio
	contract and relax to allow movement	• contains protein fibres, which can contract to make the cells shorter • contains lots of mitochondria to release energy from respiration, allowing the muscles to contract
	carry electrical impulses around the body	• branched endings, called dendrites, to make connections with other neurones or effectors • myelin sheath insulates the axon to increase the transmission speed of the electrical impulses
	absorb mineral ions and water from the soil	• long projection speeds up the absorption of water and mineral ions by increasing the surface area of the cell • lots of mitochondria to release energy for the active transport of mineral ions from the soil
	enable photosynthesis in the leaf	• lots of chloroplasts containing chlorophyll to absorb light energy • located at the top surface of the leaf where it can absorb the most light energy

Comparing diffusion, osmosis, and active transport

	Diffusion	Osmosis	Active transport
Definition	The spreading out of particles, resulting in a net movement from an area of higher **concentration** to an area of lower concentration. Factors which affect the rate of diffusion: difference in concentration, temperature, and surface area of the membrane.	The diffusion of water from a **dilute** solution to a concentrated solution through a **partially permeable membrane**.	The movement of particles from a more dilute solution to a more concentrated solution using energy from respiration.
Movement of particles	Particles move down the concentration **gradient** – from an area of *high* concentration to an area of *low* concentration.	Water moves from an area of *lower* solute concentration to an area of *higher* solute concentration.	Particles move against the concentration gradient – from an area of *low* concentration to an area of *high* concentration.
Energy required?	no – passive process	no – passive process	yes – energy released by respiration
Examples	**Humans** • Nutrients in the small intestine diffuse into the **capillaries** through the **villi**. • Oxygen diffuses from the air in the **alveoli** into the blood in the capillaries. Carbon dioxide diffuses from the blood in the capillaries into the air in the alveoli. • **Urea** diffuses from cells into the blood for excretion in the kidney. **Fish** • Oxygen from water passing over the gills diffuses into the blood in the **gill filaments**. • Carbon dioxide diffuses from the blood in the gill filaments into the water. **Plants** • Carbon dioxide used for photosynthesis diffuses into leaves through the **stomata**. • Oxygen produced during photosynthesis diffuses out of the leaves through the stomata.	**Plants** • Water moves by osmosis from a dilute solution in the soil to a concentrated solution in the **root hair cell**.	**Humans** • Active transport allows sugar molecules to be absorbed from the small intestine when the sugar concentration is higher in the blood than in the small intestine. **Plants** • Active transport is used to absorb mineral ions into the root hair cells from more dilute solutions in the soil.

Key terms

Make sure you can write a definition for these key terms.

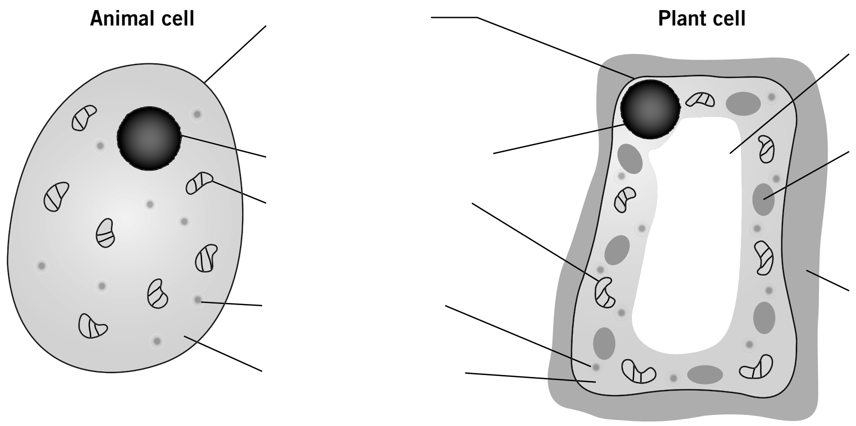
cell membrane, cell wall, chloroplast, chromosome, concentration, cytoplasm, dilute, DNA, eukaryotic, gill filaments, gradient, magnification, mitochondria, nucleus, partially permeable membrane, passive process, permanent vacuole, plasmid, prokaryotic, resolution, ribosome, root hair cell, stomata

Chapter 1: Cell biology and transport

Knowledge organiser

Eukaryotic cells

Animal and plant cells are eukaryotic. They have genetic material (DNA) that forms **chromosomes** and is contained in a **nucleus**. Label the diagram.

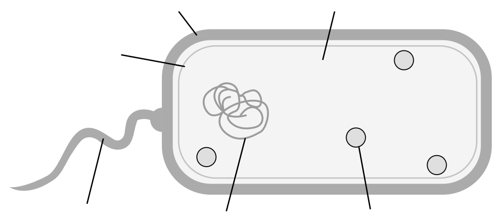


Prokaryotic cells

Bacteria have the following characteristics:

-
-
-
-

Label the diagram.



Microscopes

Light microscope	Electron microscope
	uses a beam of electrons to form images
living samples can be viewed	
relatively cheap	
	high magnification
	high resolution

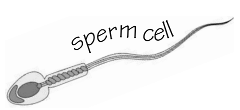
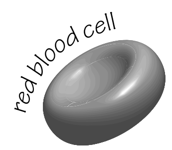
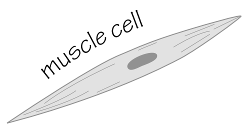
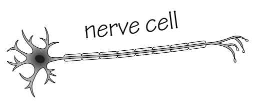
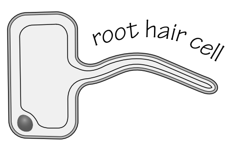
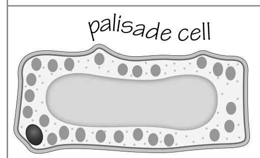
Electron microscopes allow you to see sub-cellular structures, such as ___________, that are too small to be seen with a light microscope.

To calculate the **magnification** of an image:

magnification = ___________

Specialised cells

Cells in animals and plants differentiate to form different types of cells. Most animal cells differentiate at an early stage of development, whereas a plant's cells differentiate throughout its lifetime. Complete the table.

Specialised cell	Function	Adaptations
		• •
		• • •
		• •
		• •
		• •
		• •

Comparing diffusion, osmosis, and active transport

	Diffusion	Osmosis	Active transport
Definition	The spreading out of particles, resulting in a net movement from an area of ___________ to an area of ___________. Factors which affect the rate of diffusion: ___________ ___________, ___________, and ___________ ___________.	The diffusion of water from a ___________ solution to a ___________ solution through a ___________.	The movement of particles from a more dilute solution to a more concentrated solution using energy from ___________.
Movement of particles	Particles move down the ___________ ___________ – from an area of *high* concentration to an area of *low* concentration.	Water moves from an area of *lower* ___________ concentration to an area of *higher* solute concentration.	Particles move against the concentration gradient – from an area of *low* concentration to an area of *high* concentration.
Energy required?	___________	___________	___________
Examples	**Humans** • • • **Fish** • • **Plants** • •	**Plants** •	**Humans** • **Plants** •

Key terms Make sure you can write a definition for these key terms.

cell membrane   cell wall   chloroplast   chromosome
concentration   cytoplasm   dilute   DNA   eukaryotic
gill filaments   gradient   magnification   mitochondria
nucleus   partially permeable membrane   passive process
permanent vacuole   plasmid   prokaryotic   resolution
ribosome   root hair cell   stomata

Chapter 1: Cell biology and transport

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B1 questions	Answers
1	What are two types of eukaryotic cell?	
2	What type of cell are bacteria?	
3	Where is DNA found in animal and plant cells?	
4	What is the function of the cell membrane?	
5	What is the function of mitochondria?	
6	What is the function of chloroplasts?	
7	What is the function of ribosomes?	
8	What is the function of the cell wall?	
9	What is the structure of the main genetic material in a prokaryotic cell?	
10	How are electron microscopes different to light microscopes?	
11	What is the function of a red blood cell?	
12	Give three adaptations of a red blood cell.	
13	What is the function of a nerve cell?	
14	Give two adaptations of a nerve cell.	
15	What is the function of a sperm cell?	
16	Give two adaptations of a sperm cell.	
17	What is the function of a palisade cell?	
18	Give two adaptations of a palisade cell.	
19	What is the function of a root hair cell?	
20	Give two adaptations of a root hair cell.	
21	What is diffusion?	
22	Name three factors that affect the rate of diffusion.	
23	How are villi adapted for exchanging substances?	• • •
24	How are the lungs adapted for efficient gas exchange?	• • • •
25	How are fish gills adapted for efficient gas exchange?	• • •
26	What is osmosis?	
27	Give one example of osmosis in a plant.	
28	What is active transport?	
29	Why is active transport needed in plant roots?	
30	What is the purpose of active transport in the small intestine?	

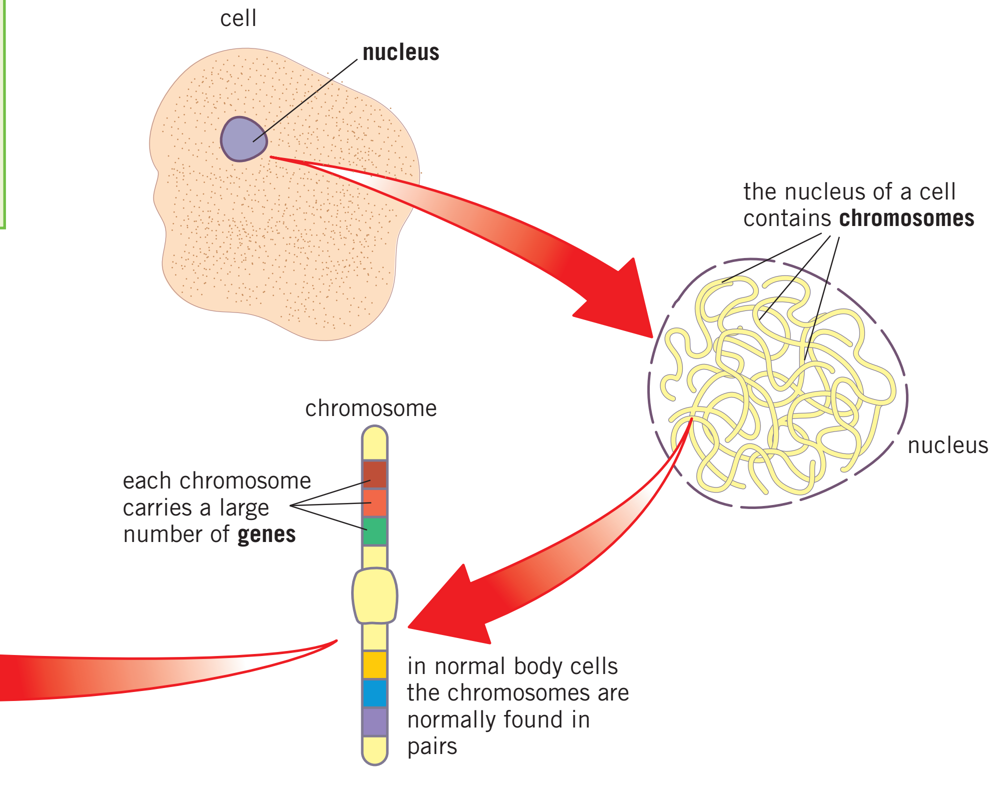
Chapter 2: Cell division

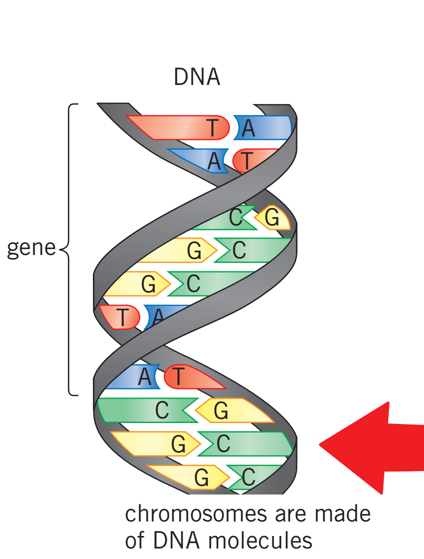
Knowledge organiser

Chromosomes

The nucleus of a cell contains chromosomes.

Each chromosome carries a large number of genes made of DNA molecules.





Stem cells in medicine

A stem cell is an undifferentiated cell that can develop into one or more types of specialised cell.

There are two types of stem cell in mammals: **adult stem cells** and **embryonic stem cells**.

Stem cells can be **cloned** to produce large numbers of identical cells.

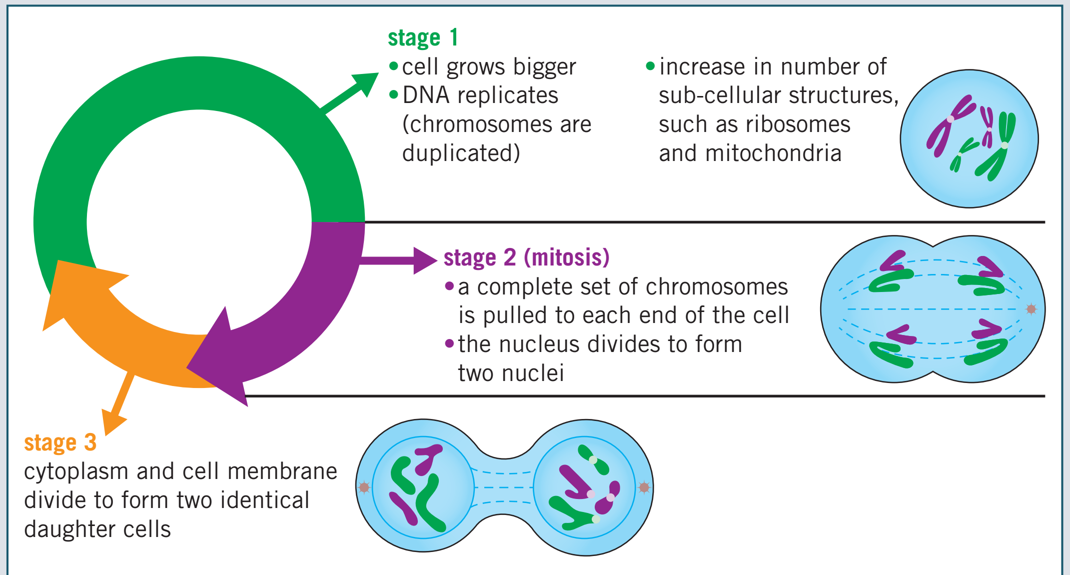
Type of stem cell	Where are they found?	What can they differentiate into?	Advantages	Disadvantages
adult stem cells	specific parts of the body in adults and children – for example, bone marrow	can only differentiate to form certain types of cells – for example, stem cells in bone marrow can only differentiate into types of blood cell	• fewer ethical issues – adults can consent to have their stem cells removed and used • an already established technique for treating diseases such as leukaemia • relatively safe to use as a treatment and donors recover quickly	• requires a donor, potentially meaning a long wait time to find someone suitable • can only differentiate into certain types of specialised cells, so can be used to treat fewer diseases
embryonic stem cells	early human embryos (often taken from spare embryos from fertility clinics)	can differentiate into any type of specialised cell in the body – for example, a nerve cell or a muscle cell	• can treat a wide range of diseases as can form any specialised cell • may be possible to grow whole replacement organs • usually no donor needed as they are obtained from spare embryos from fertility clinics	• ethical issues as the embryo is destroyed and each embryo is a potential human life • risk of transferring viral infections to the patient • newer treatment so relatively under-researched – not yet clear if they can cure as many diseases as thought
plant meristem	meristem regions in the roots and shoots of plants	can differentiate into all cell types – they can be used to create clones of whole plants	• rare species of plants can be cloned to prevent extinction • plants with desirable traits, such as disease resistance, can be cloned to produce large numbers of identical plants • fast and low-cost production of large numbers of plants	• cloned plants are genetically identical, so a whole crop is at risk of being destroyed by a single disease or genetic defect

The cell cycle

Body cells divide to form two identical **daughter cells** by going through a series of stages known as the **cell cycle**.

Cell division by **mitosis** is important for the growth and repair of cells, for example, the replacement of skin cells. Mitosis is also used for asexual reproduction.

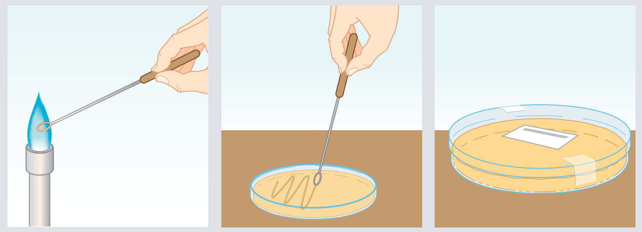
There are *three* main stages in the cell cycle:



Binary fission

Cell division in bacteria is called binary fission. In optimum temperature and nutrients, bacteria can multiply as often as every 20 minutes. In a lab, bacteria can be grown in sterile conditions on an agar gel plate or in a nutrient broth.

The lid of the petri dish must be sealed but not all the way so that oxygen can still get in. This is so that harmful bacteria that do not need oxygen aren't able to grow.



Therapeutic cloning

In **therapeutic cloning**

- cells from a patient's own body are used to create a cloned early embryo of themselves
- stem cells from this embryo can be used for medical treatments and growing new organs
- these stem cells have the same genes as the patient, so are less likely to be rejected when transplanted.

Key terms

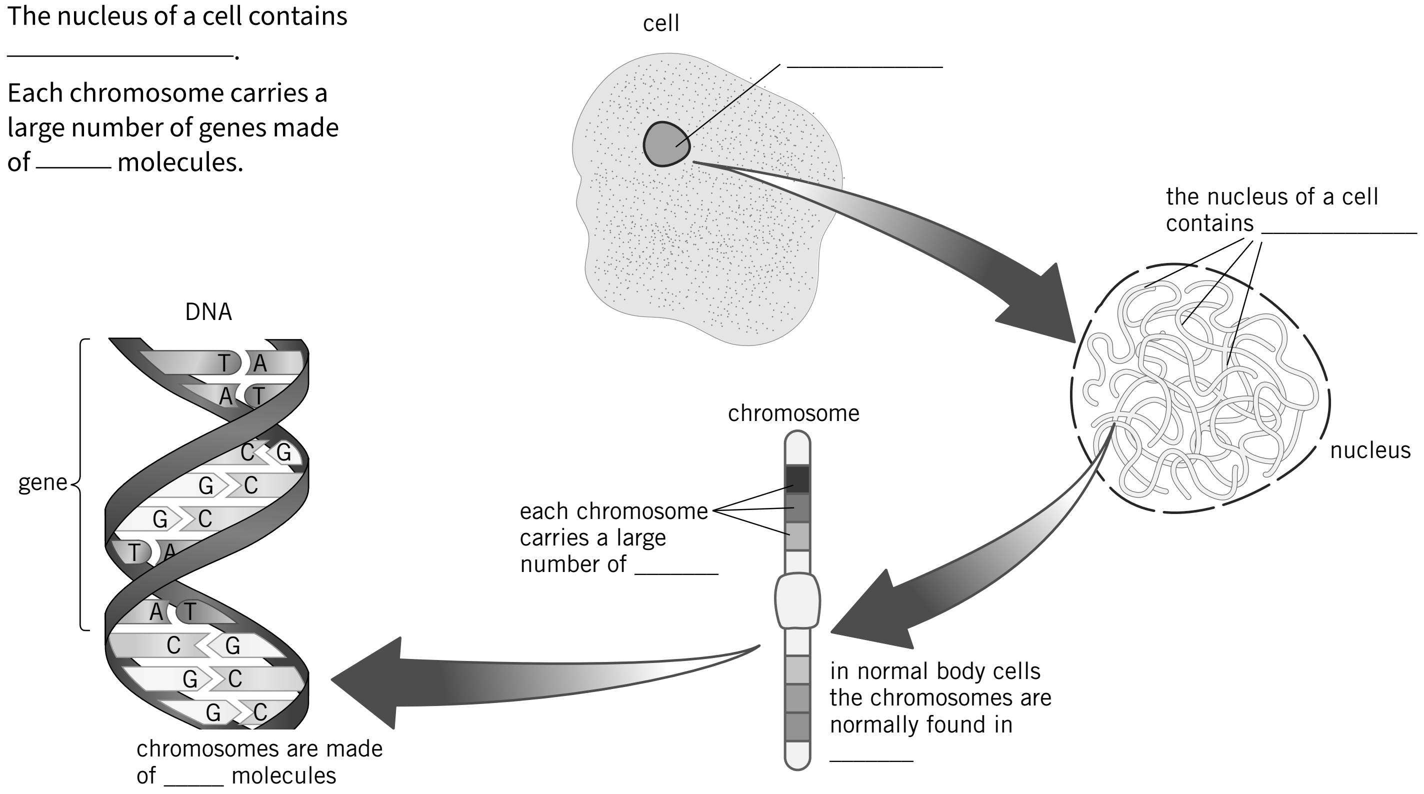
Make sure you can write a definition for these key terms.

adult stem cell, binary fission, cell cycle, chromosome, clone, daughter cells, embryonic stem cell, gene, meristem, mitosis, nucleus, therapeutic cloning

Chromosomes

The nucleus of a cell contains ________________.

Each chromosome carries a large number of genes made of ______ molecules.



Stem cells in medicine

A stem cell is an undifferentiated cell that can develop into one or more types of ____________ cell.

There are two types of stem cell in ____________: **adult stem cells** and ____________ **stem cells**.

Stem cells can be ____________ to produce large numbers of identical cells. Complete the table.

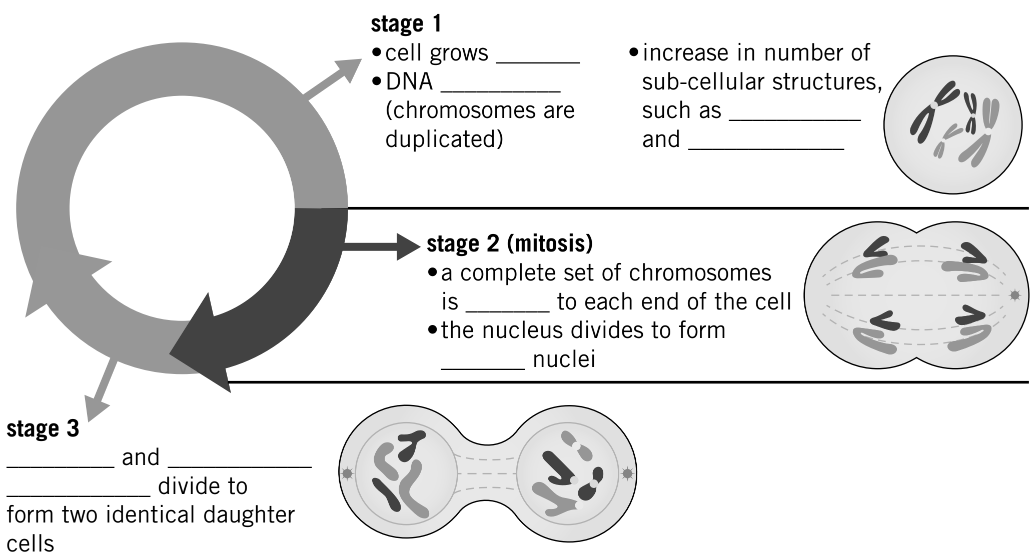
Type of stem cell	Where are they found?	What can they differentiate into?	Advantages	Disadvantages
adult stem cells			• • •	• •
embryonic stem cells			• • •	• • •
plant meristem			• • •	•

The cell cycle

Body cells divide to form ________ identical **daughter cells** by going through a series of stages known as the **cell cycle**.

Cell division by ____________ is important for the growth and ____________ of cells, for example, the replacement of skin cells. Mitosis is also used for ____________ reproduction.

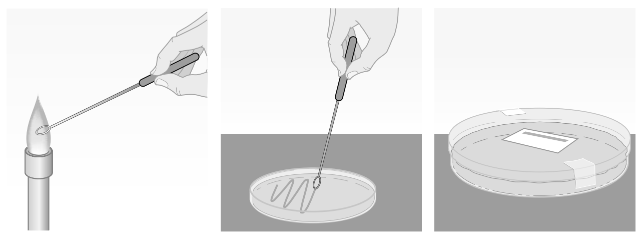
There are *three* main stages in the cell cycle:



Binary fission

Cell division in ____________ is called binary fission. In optimum ____________ and ____________, bacteria can multiply as often as every 20 minutes. In a lab, bacteria can be grown in ____________ conditions on an agar gel plate or in a nutrient broth.

The lid of the petri dish must be sealed but not all the way so that ____________ can still get in. This is so that harmful ____________ that do not need oxygen aren't able to grow.



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- these stem cells have the same genes as the patient, so are less likely to be ____________ when transplanted.

Key terms

Make sure you can write a definition for these key terms.

adult stem cell, binary fission, cell cycle, chromosome, clone, daughter cells, embryonic stem cell, gene, meristem, mitosis, nucleus, therapeutic cloning

Chapter 2: Cell division

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B2 questions	Answers
1	What is a stem cell?	
2	What are adult stem cells?	
3	Where can adult stem cells be found?	
4	What are embryonic stem cells?	
5	Where are embryonic stem cells found?	
6	What is therapeutic cloning?	
7	Give one advantage of using therapeutic cloning.	
8	Give one advantage of using adult stem cells.	
9	Give two disadvantages of using adult stem cells.	•
10	Give two advantages of using embryonic stem cells.	• •
11	Give two disadvantages of using embryonic stem cells.	• •
12	What are plant meristems?	
13	Give two advantages of using plant meristems to clone plants.	• •
14	Give one disadvantage of using plant meristems to clone plants.	
15	What is cell division by mitosis?	
16	What is the purpose of mitosis?	
17	What happens during the first stage of the cell cycle?	
18	What happens during mitosis?	
19	What happens during the third stage of the cell cycle?	
20	What is the term for cell division in bacteria?	

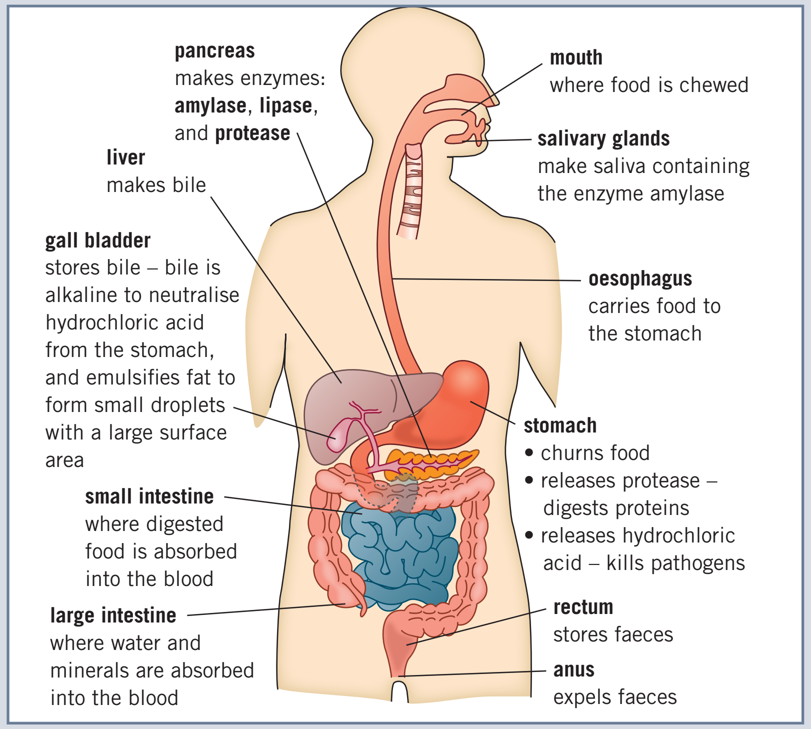
Chapter 3: Organisation and the digestive system

Knowledge organiser

There are five **levels of organisation** in living organisms:

cells	basic building blocks
tissues	groups of cells that have similar structures and functions
organs	groups of tissues working together to perform a specific function
organ systems	groups of organs working together
organisms	organ systems work together, forming an organism

Digestive system



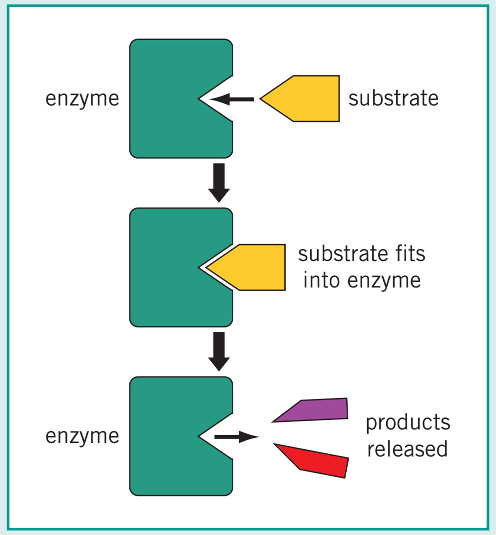
Digestive enzymes

Digestive enzymes convert food into small, soluble molecules that can then be absorbed into the bloodstream. For example, carbohydrases break down carbohydrates into simple sugars.

Enzyme	Sites of production	Reaction catalysed
amylase	salivary glands pancreas small intestine	starch → glucose
proteases	stomach pancreas small intestine	proteins → amino acids
lipases	pancreas small intestine	lipids → fatty acids and glycerol

Enzymes

Enzymes are large proteins that **catalyse** (speed up) reactions. Enzymes are not changed in the reactions they catalyse.



Lock and key theory

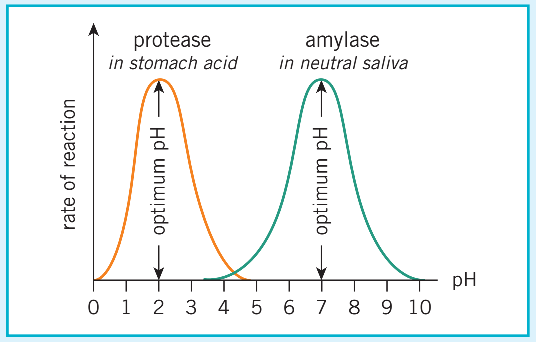
This is a simple model of how enzymes work:

1. The enzyme's **active site** (where the reaction occurs) is a specific shape.
2. The enzyme (the lock) will only catalyse a specific reaction because the **substrate** (the key) fits into its active site.
3. At the active site, enzymes can break molecules down into smaller ones or bind small molecules together to form larger ones.
4. When the products have been released, the enzyme's active site can accept another substrate molecule.

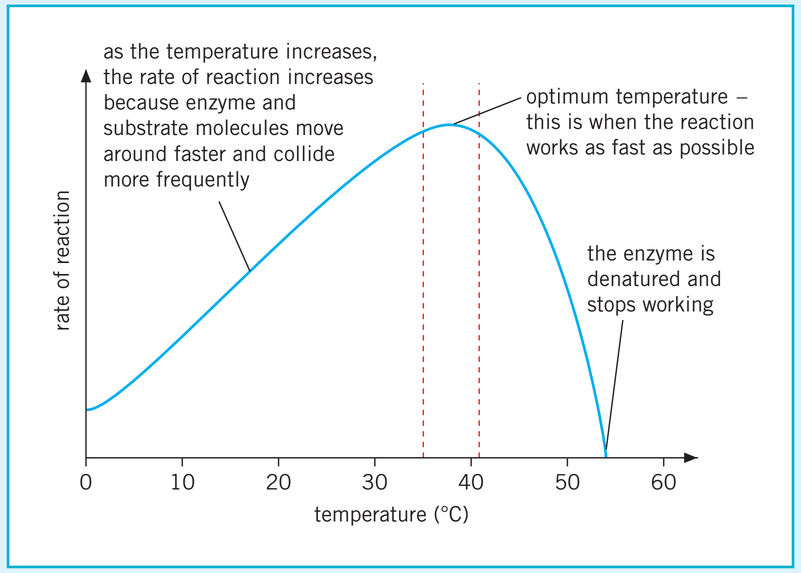
The effect of pH on enzymes

Different enzymes have different **optimum** pH values.

This allows enzymes to be adapted to work well in environments with different pH values. For example, parts of the digestive system greatly differ in pH.

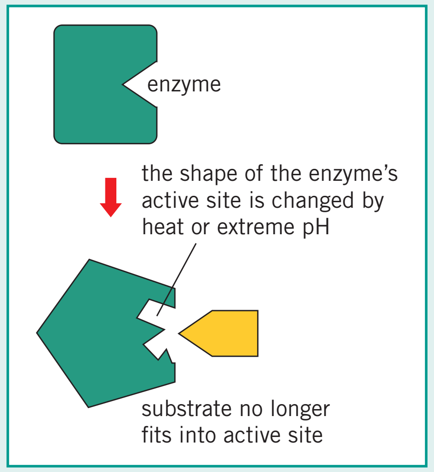


The effect of temperature on enzymes



Denaturation

At extremes of pH or at very high temperatures, the shape of an enzyme's active site can change.



The substrate can no longer bind to the active site, so the enzyme cannot catalyse the reaction – the enzyme has been **denatured**.

Key terms

Make sure you can write a definition for these key terms.

active site   amylase   catalyse   denatured   enzyme   lipase   optimum   organ   organ system
pH   protease   substrate   temperature   tissue

Chapter 3: Organisation and the digestive system

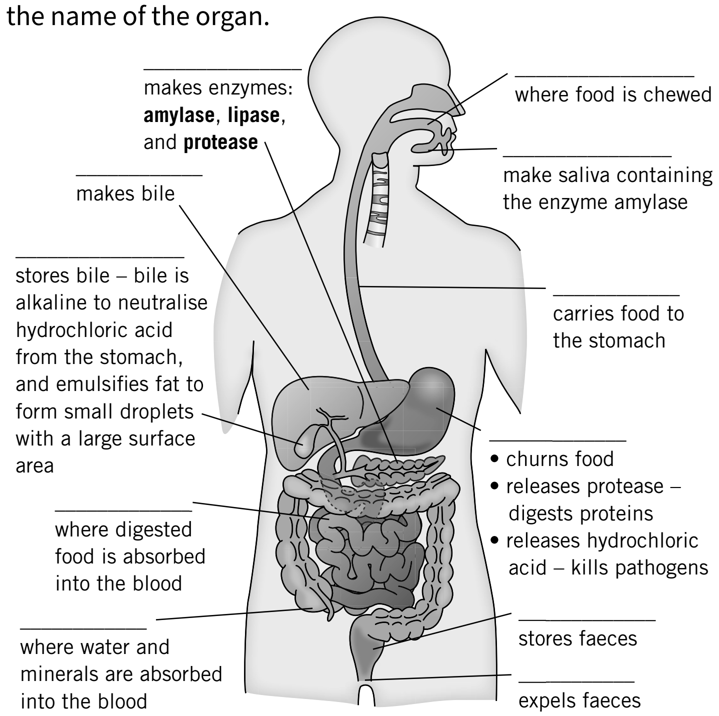
Knowledge organiser

There are five **levels of organisation** in living organisms. Complete the definitions for each level.

- **cells** ________________
- **tissues** ________________ ________________ ________________
- **organs** ________________ ________________ ________________
- **organ systems** ________________ ________________
- **organisms** ________________ ________________ ________________

Digestive system

Write the name of the organ.



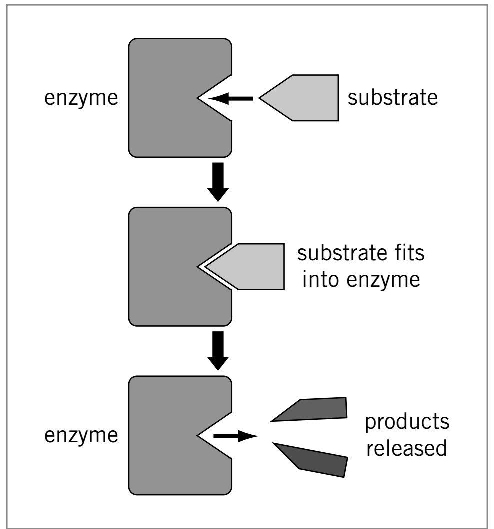
Digestive enzymes

Digestive enzymes convert food into small, soluble molecules that can then be absorbed into the ____________. For example, carbohydrases break down ________________ into ________________.

Enzyme	Sites of production	Reaction catalysed
____________	salivary glands pancreas small intestine	starch → glucose
proteases	________________ ________________ ________________	________________
lipases	________________ ________________	________________

Enzymes

Enzymes are large proteins that ________ (speed up) reactions. Enzymes are not changed in the reactions they catalyse.



Lock and key theory

This is a simple model of how enzymes work:

1 The enzyme's ________ ________ (where the reaction occurs) is a specific shape.

2 The ________ (the lock) will only catalyse a specific reaction because the ________ (the key) fits into its active site.

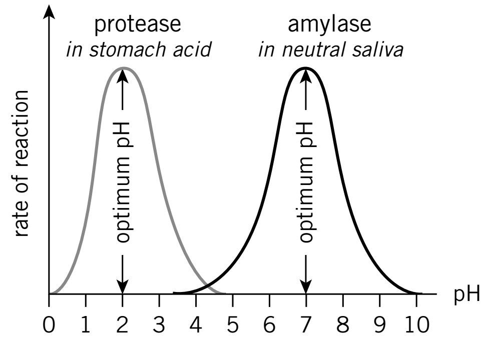
3 At the active site, enzymes can ________ molecules down into smaller ones or bind small molecules together to form ________ ones.

4 When the products have been released, the enzyme's active site can accept another substrate molecule.

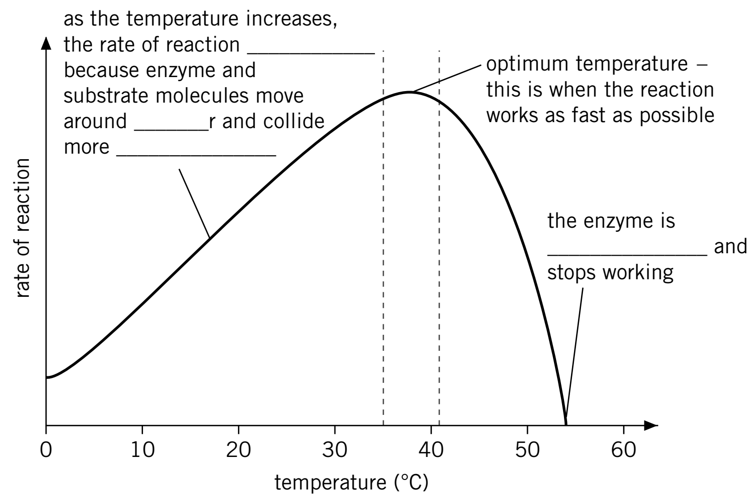
The effect of pH on enzymes

Different enzymes have different ________ pH values.

This allows enzymes to be adapted to work well in environments with different pH values. For example, parts of the digestive system greatly differ in ________.

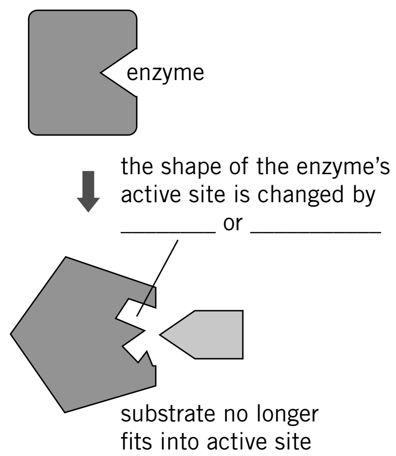


The effect of temperature on enzymes



Denaturation

At extremes of pH or at very high temperatures, the shape of an enzyme's active site can change.



The substrate can no longer ________ to the active site, so the enzyme cannot catalyse the reaction – the enzyme has been **denatured**.

Key terms

Make sure you can write a definition for these key terms.

active site *amylase* *catalyse* *denatured* *enzyme* *lipase* *optimum* *organ* *organ system* *pH* *protease* *substrate* *temperature* *tissue*

Chapter 3: Organisation and digestive system

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

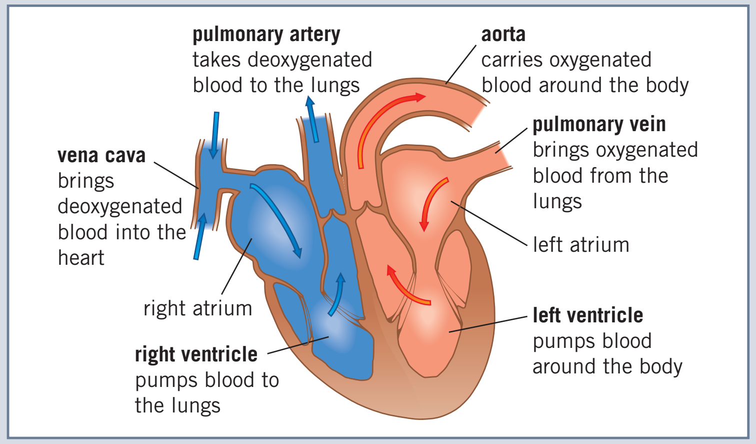
	B3 questions	Answers
1	Name the five levels of organisation.	
2	What is a tissue?	
3	What is an organ?	
4	What is the function of the liver in digestion?	
5	What is the function of saliva in digestion?	
6	Name three enzymes produced in the pancreas.	
7	What are enzymes?	
8	Why are enzymes described as specific?	
9	Describe the function of amylase.	
10	Where is amylase produced?	
11	Describe the function of proteases.	
12	Where are proteases produced?	
13	Describe the function of lipases.	
14	Where are lipases produced?	
15	What are two factors that affect the rate of activity of an enzyme?	
16	What does denatured mean?	
17	Describe the effect of temperature on enzyme activity.	
18	Describe the effect of pH on enzyme activity.	
19	Why do different digestive enzymes have different optimum pHs?	
20	What is an organ system?	

Chapter 4: Organising animals and plants 1

Knowledge organiser

The heart

The heart is the organ that pumps blood around your body. It is made from **cardiac** muscle tissue, which is supplied with oxygen by the **coronary artery**.



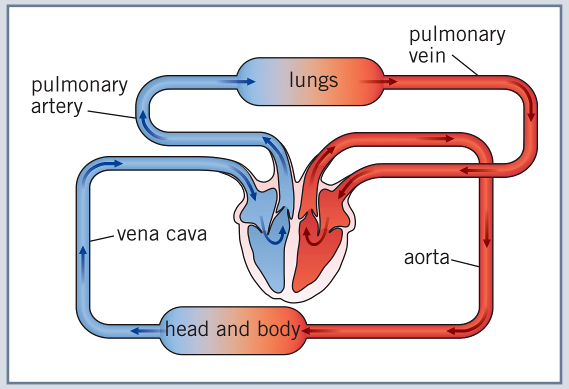
Heart rate is controlled by a group of cells in the right atrium that generate electrical impulses, acting as a pacemaker.

Artificial pacemakers can be used to control irregular heartbeats.

Double circulatory system

The human circulatory system is described as a **double circulatory system** because blood passes through the heart twice for every circuit around the body:

- the right ventricle pumps blood to the lungs where gas exchange takes place
- the left ventricle pumps blood around the rest of the body.

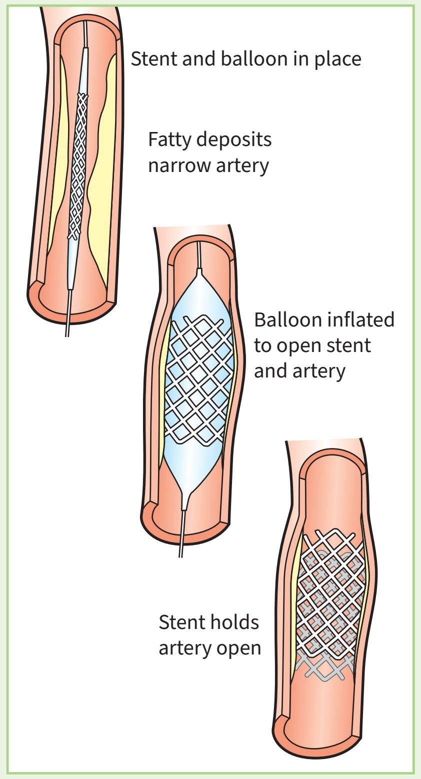


Heart issues

Coronary heart disease is caused by a build up of fatty material in the coronary arteries, making them narrow, and reducing blood flow. Stents can be used to help keep the coronary arteries open.

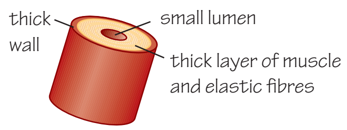
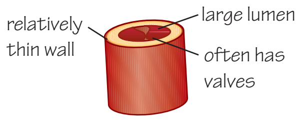
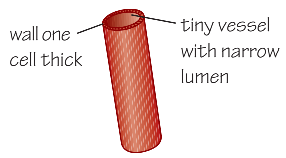
Patients with heart failure often have to use artificial hearts before a donor heart becomes available for a heart transplant.

People with faulty heart **valves** may feel symptoms of breathlessness as valves do not fully open, making the heart less efficient. These can be replaced with biological valves (from animals), or mechanical valves (made from titanium and polymers).



blood is a tissue made up of four main components	
	• red blood cells – bind to oxygen and transport it around the body • plasma – transports substances and blood cells around the body • platelets – form blood clots to create barriers to infections • white blood cells – part of the immune system to defend the body against pathogens

Blood vessels

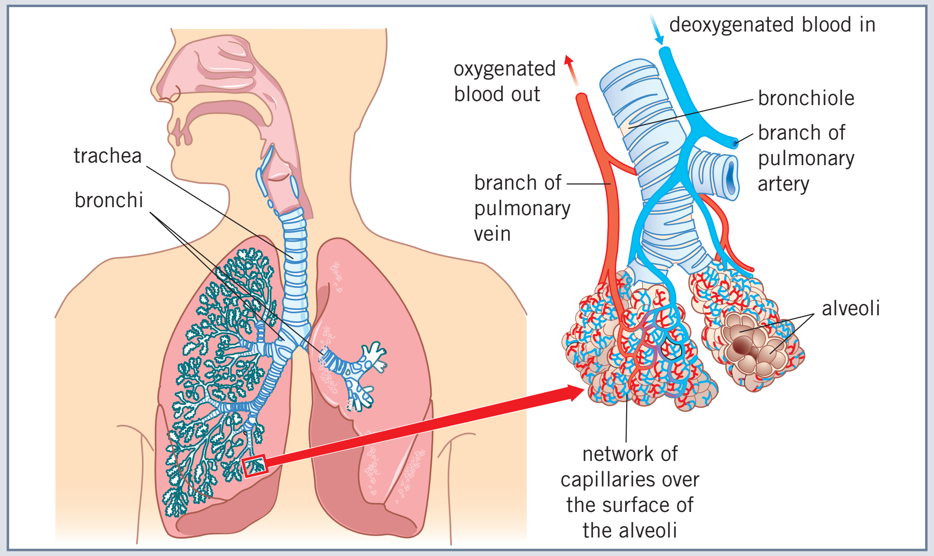
Vessel	Function	Structure	Diagram
artery	carries blood away from the heart (high pressure)	• thick, muscular, and elastic walls • the walls can stretch and withstand high pressure • small lumen	
vein	carries blood to the heart (low pressure)	• have valves to stop blood flowing the wrong way • thin walls • large lumen	
capillary	• carries blood to tissues and cells • connects arteries and veins	• one cell thick – short diffusion distance for substances to move between the blood and tissues (e.g., oxygen into cells and carbon dioxide out) • very narrow lumen	

Lungs

When breathing in, air moves

1. into the body through the mouth and nose
2. down the trachea
3. into the **bronchi**
4. through the **bronchioles**
5. into the **alveoli** (air sacs).

Oxygen then diffuses into the blood in the network of **capillaries** over the surface of the alveoli.



Key terms

Make sure you can write a definition for these key terms.

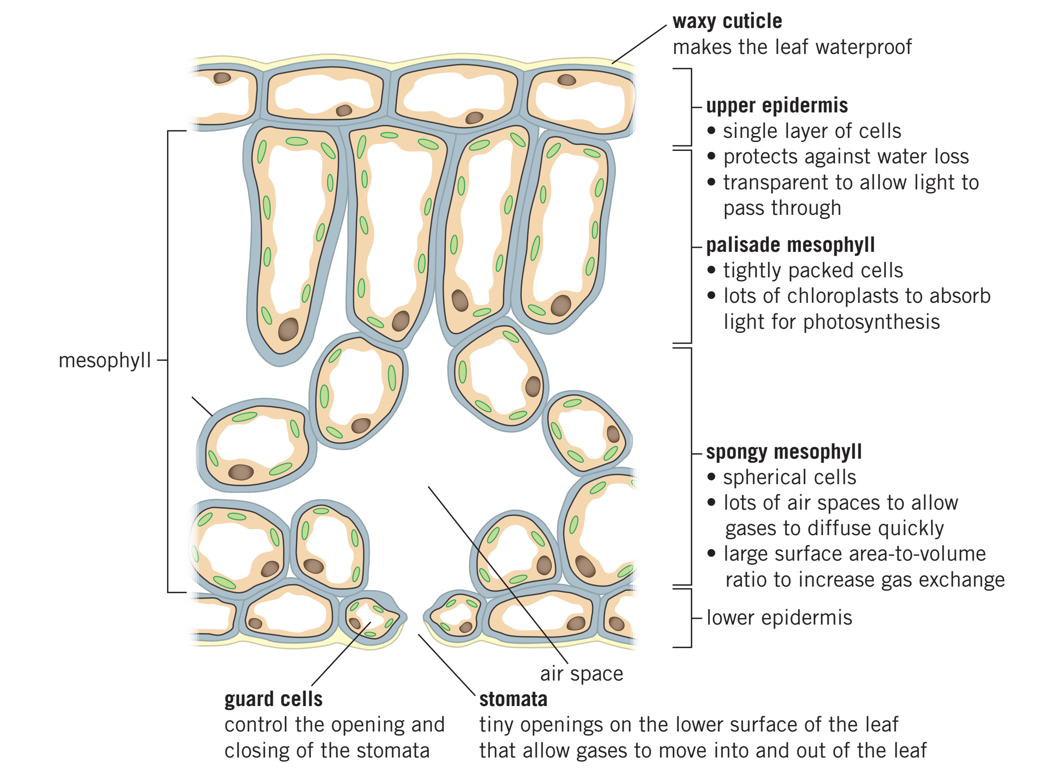
alveoli aorta artery atrium bronchi bronchiole capillary cardiac coronary double circulatory system plasma platelet pulmonary valve vein vena cava ventricle

Chapter 4: Organising animals and plants 2

Knowledge organiser

Tissues in leaves

Leaves are organs because they contain many tissues that work together to perform photosynthesis.



Stomata

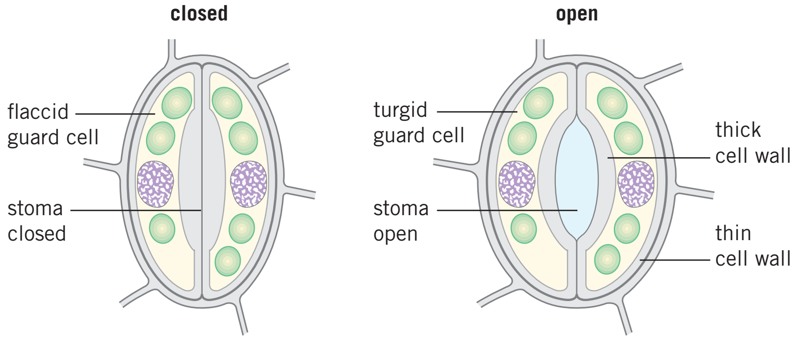
Stomata are tiny openings in the undersides of leaves – this placement reduces water loss through evaporation.

They control gas exchange and water loss from leaves by:

- allowing diffusion of carbon dioxide into the plant for photosynthesis
- allowing diffusion of oxygen out of the plant.

Guard cells are used to open and close the stomata.

When a plant has plenty of water, the guard cells become turgid. The cell wall on the inner surface is very thick, so it cannot stretch as much as the outer surface. So as the guard cells swell up, they curve away from each other, opening the stoma.



Transpiration

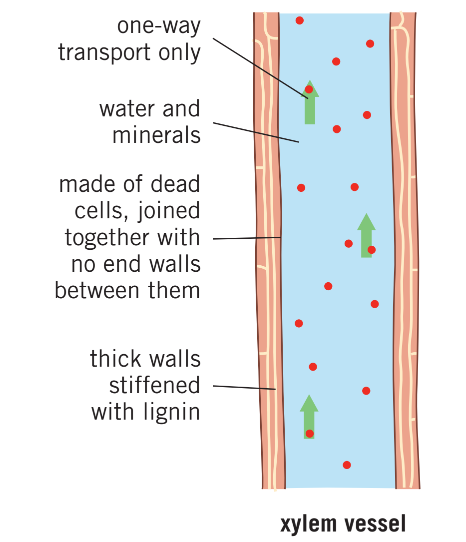
Description

Water is lost through the stomata by evaporation. This pulls water up from the roots through the **xylem** and is called transpiration. The constant movement of water up the plant is called the **transpiration stream**.

Importance

- provides water to cells to keep them **turgid**
- provides water to cells for photosynthesis
- transports mineral ions to leaves

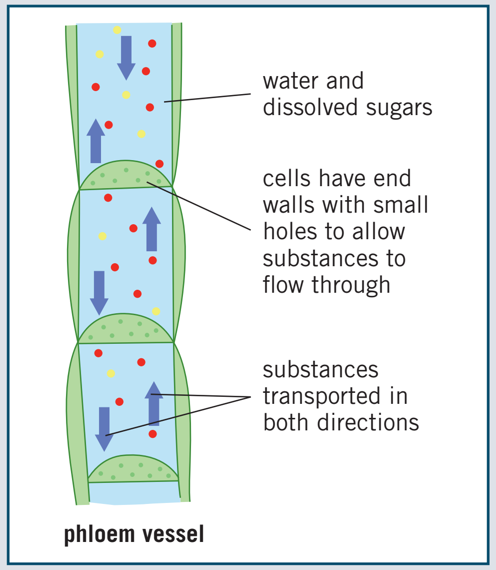
Specialised tissues



Translocation

The movement of dissolved sugars from the leaves to the rest of the plant through the **phloem**.

- moves dissolved sugars made in the leaves during photosynthesis to other parts of the plant
- this allows for respiration, growth, and glucose storage



Factors affecting the rate of transpiration

Factor	Effect on transpiration	Because…
temperature	higher temperatures *increase* the rate of transpiration	water evaporates faster in higher temperatures
humidity	lower humidity *increases* the rate of transpiration	the drier the air, the steeper the concentration gradient of water molecules between the air and leaf
wind speed	more wind *increases* the rate of transpiration	wind removes the water vapour quickly, maintaining a steeper concentration gradient
light intensity	higher light intensity *increases* the rate of transpiration	stomata open wider to let more carbon dioxide into the leaf for photosynthesis

Key terms

Make sure you can write a definition for these key terms.

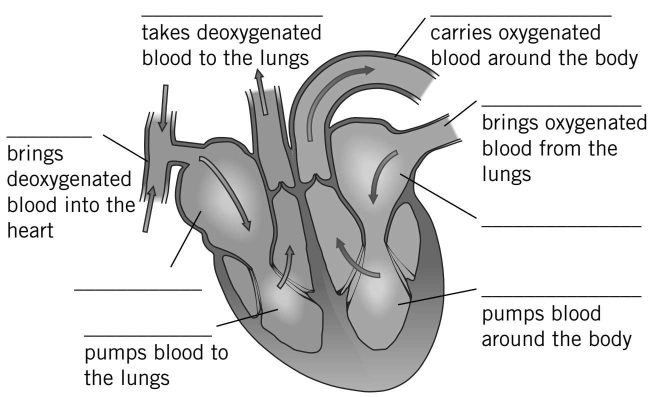
photosynthesis stomata guard cells transpiration translocation
light intensity temperature humidity wind speed phloem xylem

Chapter 4: Organising animals and plants 1

Knowledge organiser

The heart

The heart is the organ that pumps ________ around your body. It is made from ________ muscle tissue, which is supplied with oxygen by the ________ **artery**. Complete the labels on the diagram.



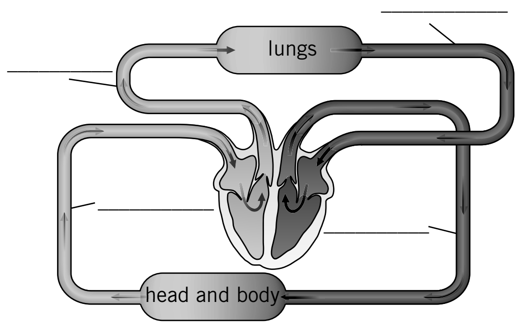
Heart rate is controlled by a group of cells in the ________ that generate ____________, acting as a pacemaker.

Artificial pacemakers can be used to control ______________.

Double circulatory system

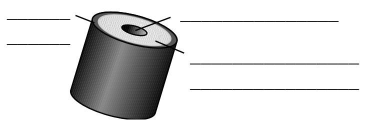
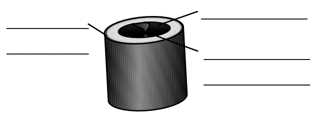
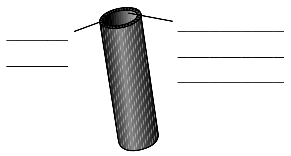
The human circulatory system is described as a __________ __________ __________ because blood passes through the heart ________ for every circuit around the body:

- the right ventricle pumps blood to the ________ where gas exchange takes place
- the ______________ ______________ pumps blood around the rest of the body.



blood is a tissue made up of ________ main components	
	• ______________ – bind to oxygen and transport it around the body • ____________ – transports substances and blood cells around the body • ____________ – form blood clots to create barriers to infections • ______________ – part of the immune system to defend the body against pathogens

Blood vessels

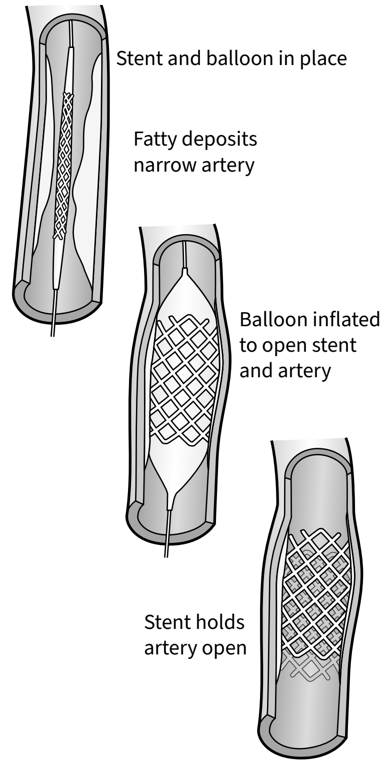
Vessel	*Function*	*Structure*	*Diagram*
artery	______________________ ______________________	• • •	
vein		• • •	
capillary	• •	• •	

Heart issues

Coronary heart disease is caused by a build up of fatty material in the ________ arteries, making them ________, and reducing ____________ ____________. __________ can be used to help keep the coronary arteries open.

Patients with heart failure often have to use ____________ ____________ before a donor heart becomes available for a heart transplant.

People with faulty heart **valves** may feel symptoms of breathlessness as valves do not fully ________, making the heart less efficient. These can be replaced with ____________ ____________ (from animals), or ______________ ____________ (made from titanium and polymers).



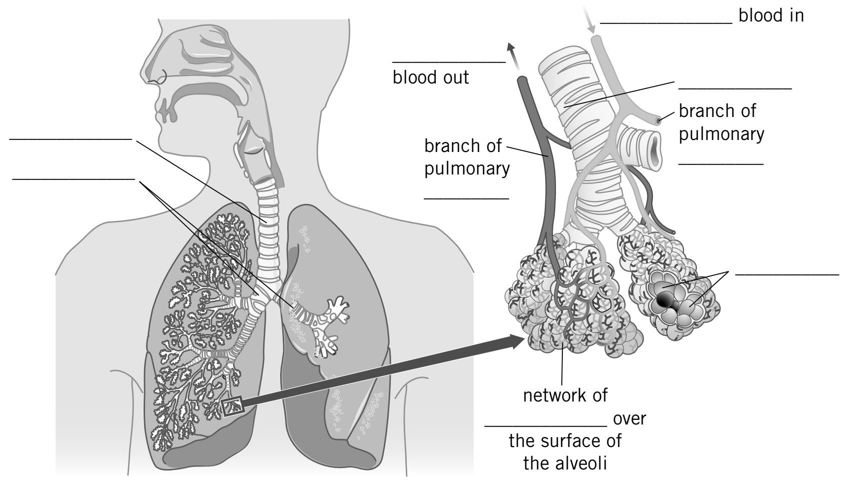
Lungs

When breathing in, air moves

1. into the body through the mouth and nose
2. down the __________
3. into the __________
4. through the __________
5. into the ________ (air sacs).

Oxygen then diffuses into the blood in the network of ________ over the surface of the alveoli.

Label the diagram.



Key terms

Make sure you can write a definition for these key terms.

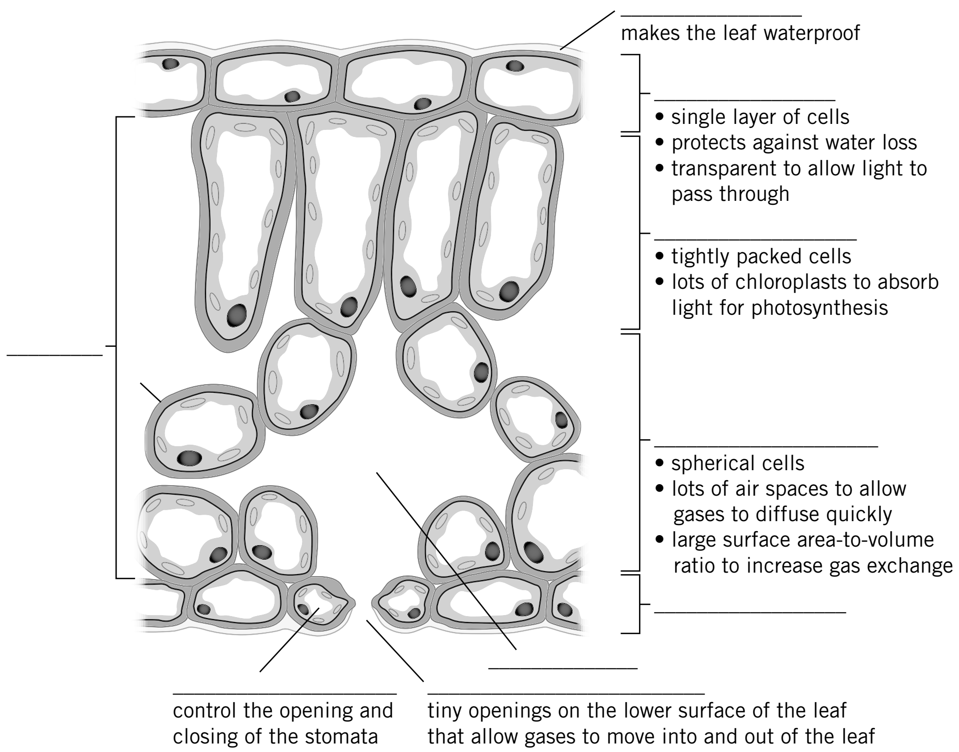
alveoli aorta artery atrium bronchi bronchiole capillary cardiac coronary double circulatory system plasma platelet pulmonary valve vein vena cava ventricle

Chapter 4: Organising animals and plants 2

Knowledge organiser

Tissues in leaves

Leaves are ____________ because they contain many tissues that work together to perform ______________.



Stomata

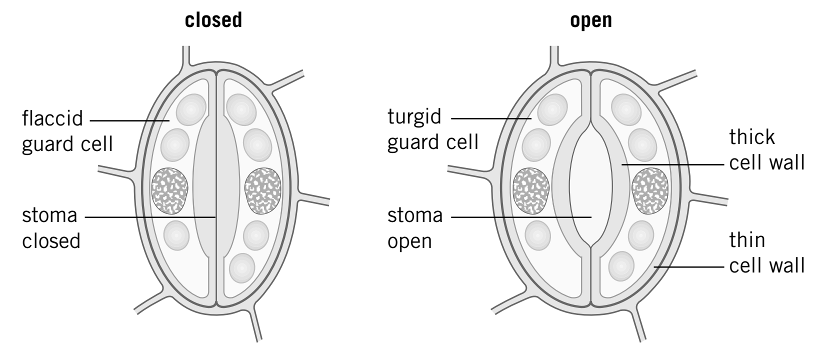
________ are tiny openings in the undersides of leaves – this placement reduces water loss through ________.

They control gas exchange and water loss from leaves by:

- allowing ________ of _______________ into the plant for photosynthesis
- allowing diffusion of ________ out of the plant.

_____________ _____________ are used to open and close the stomata.

When a plant has plenty of water, the guard cells become ________. The cell wall on the inner surface is very ________, so it cannot stretch as much as the outer surface. So as the guard cells ________ up, they curve away from each other, opening the ________.



Transpiration

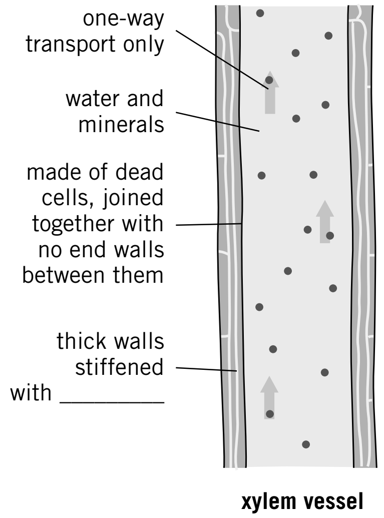
Description

Water is lost through the stomata by evaporation. This pulls water up from the roots through the ________ and is called __________. The constant ________ of water up the plant is called the ___________ ___________.

Importance

- provides water to cells to keep them ________
- provides ________ to cells for photosynthesis
- transports ___________ to leaves

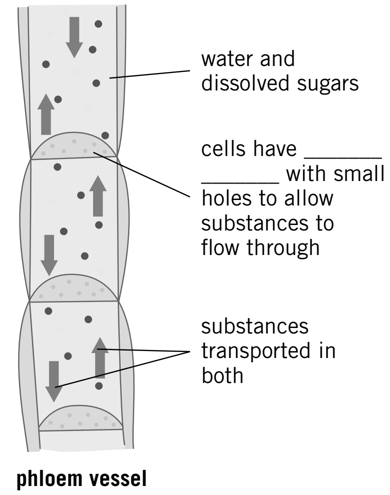
Specialised tissues



Translocation

The movement of dissolved sugars from the leaves to the rest of the plant through the ________.

- moves dissolved sugars made in the leaves during ____________ to other parts of the plant
- this allows for ________, growth, and ________ storage



Factors affecting the rate of transpiration

Factor	Effect on transpiration	Because...
temperature		
humidity		
wind speed		
light intensity		

Key terms **Make sure you can write a definition for these key terms.**

photosynthesis *stomata* *guard cells* *transpiration* *translocation*
light intensity *temperature* *humidity* *wind speed* *phloem* *xylem*

Chapter 4: Organising animals and plants

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B4 questions	Answers
1	Name the four main components of blood.	
2	What is the function of platelets?	
3	Why is the human circulatory system a double circulatory system?	
4	How does the structure of an artery relate to its function?	
5	How does the structure of a vein relate to its function?	
6	How does the structure of a capillary relate to its function?	
7	List the structures air passes through when breathing in.	
8	What is the function of the red blood cells?	
9	What is the function of the white blood cells?	
10	What is the function of the plasma?	
11	Why is a leaf an organ?	
12	How is the upper epidermis adapted for its function?	• •
13	How is the palisade mesophyll adapted for its function?	
14	How is the spongy mesophyll adapted for its function?	
15	What is the function of the guard cells?	
16	What is the function of the xylem?	
17	Give three adaptations of the xylem.	• • •
18	What is the function of the phloem?	
19	What is the purpose of translocation?	
20	Define the term transpiration.	
21	What is the purpose of transpiration?	• • •
22	Name four factors that affect the rate of transpiration.	
23	What effect does temperature have on the rate of transpiration?	
24	What effect does humidity have on the rate of transpiration?	
25	Why does increased light intensity increase the rate of transpiration?	
26	What is the function of the stomata?	
27	Where are most stomata found?	
28	What is the advantage to the plant of having a high number of stomata at this location?	

Chapter 5: Communicable diseases

Knowledge organiser

Communicable diseases

Communicable diseases can be spread from one organism to another.

Viruses live and reproduce rapidly inside an organism's cells. This can damage or destroy the cells.

Viruses	Spread by	Symptoms
measles	inhalation of droplets produced by infected people when sneezing and coughing	• fever • red skin rash • complications can be fatal – young children are vaccinated to immunise them against measles
HIV (human immunodeficiency virus)	• sexual contact • exchange of body fluids (e.g., blood when drug users share needles)	• flu-like symptoms at first • virus attacks the body's immune cells, which can lead to AIDS – where the immune system is so damaged that it cannot fight off infections or cancers
TMV (tobacco mosaic virus – plants)	• direct contact of plants with infected plant material • animal and plant vectors • soil: the pathogen can remain in soil for decades	• mosaic pattern of discolouration on the leaves – where chlorophyll is destroyed • reduces plant's ability to photosynthesise, affecting growth

Bacteria reproduce rapidly inside organisms and may produce **toxins** that damage tissues and cause illness.

Bacteria	Spread by	Symptoms	Prevention and treatment
Salmonella	bacteria in or on food that is being ingested	*Salmonella* bacteria and the toxins they produce cause • fever • abdominal cramps • vomiting • diarrhoea	poultry are vaccinated against *Salmonella* bacteria to control spread
gonorrhoea	direct sexual contact – gonorrhoea is a **sexually transmitted disease** (STD)	• thick yellow or green discharge from the vagina or penis • pain when urinating	• treatment with antibiotics (many antibiotic-resistant strains have appeared) • barrier methods of contraception, such as condoms

Fungi	Spread by	Symptoms	Prevention and treatment
rose black spot	water and wind	• purple or black spots on leaves, which turn yellow and drop early • reduces plant's ability to photosynthesise, affecting growth	• **fungicides** • affected leaves removed and destroyed

Protists	Spread by	Symptoms	Prevention and treatment
malaria	mosquitos feed on the blood of infected people and spread the protist pathogen when they feed on another person – organisms that spread disease by carrying pathogens between people are called **vectors**	• recurrent episodes of fever • can be fatal	• prevent mosquito vectors breeding • mosquito nets to prevent bites • anti-malarial medicine

Detection and identification of plant diseases

Signs that a plant is diseased

- stunted growth
- spots on leaves
- areas of rot or decay
- growths
- malformed stems or leaves
- discolouration
- pest infestation

Ways of identifying plant diseases

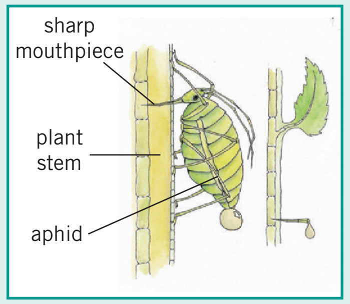
- gardening manuals and websites
- laboratory testing of infected plants
- testing kits containing monoclonal antibodies (Chapter 9 *Monoclonal antibodies*)

Plant diseases and insects

Plant diseases can also be directly caused by insects.

Aphids are insects that suck sap from the stems of plants. This results in

- reduced rate of growth
- wilting
- discolouration of leaves.



Ladybirds can be used to control aphid infestations as ladybird larvae eat aphids.

Plant defences

Physical barriers

- cellulose cell walls – provide a barrier to infection
- tough waxy cuticle on leaves
- bark on trees – a layer of dead cells that can fall off

Chemical barriers

- many plants produce antibacterial chemicals
- poison production stops animals eating plants

Mechanical adaptations

- thorns and hairs stop animals eating plants
- leaves that droop or curl when touched to scare herbivores or dislodge insects
- some plants **mimic** the appearance of unhealthy or poisonous plants to deter insects or herbivores

Controlling the spread of communicable disease

There are a number of ways to help prevent the spread of communicable diseases from one organism to another.

Hygiene

Hand washing, disinfecting surfaces and machinery, keeping raw meat separate, covering mouth when coughing/sneezing, etc.

Isolation

Isolation of infected individuals – people, animals, and plants can be isolated to stop the spread of disease.

Controlling vectors

If a vector spreads a disease destroying or controlling the population of the vector can limit the spread of disease.

Vaccination

Vaccination can protect large numbers of individuals against diseases.

Key terms

Make sure you can write a definition for these key terms.

aphid, bacterium, communicable disease, fungicide, fungus, isolation, mimic, pathogen, protist, sexually transmitted disease (STD), toxin, vaccination, vector, virus

Chapter 5: Communicable diseases

Knowledge organiser

Communicable diseases

Communicable diseases can be spread from one ____________ to another.

Viruses live and ________ rapidly inside an organism's cells. This can damage or destroy the cells.

Viruses

	Spread by	Symptoms
measles	inhalation of ____________ produced by infected people when sneezing and coughing	• •
HIV (human immunodeficiency virus)	• •	• •
TMV (tobacco mosaic virus – plants)	• • •	• •

Bacteria reproduce rapidly inside organisms and may produce that damage tissues and cause illness.

Bacteria

	Spread by	Symptoms	Prevention and treatment
Salmonella		*Salmonella* bacteria and the toxins they produce cause: • • • •	
gonorrhoea		• •	• •

Fungi

	Spread by	Symptoms	Prevention and treatment
rose black spot		• •	• •

Protists

	Spread by	Symptoms	Prevention and treatment
malaria	mosquitos feed on the blood of infected people and spread the protist pathogen when they feed on another person – organisms that spread disease by carrying pathogens between people are called ______________	• •	• • •

Detection and identification of plant diseases

Signs that a plant is diseased

-
-
-
-
-
-
-

Ways of identifying plant diseases

-
-
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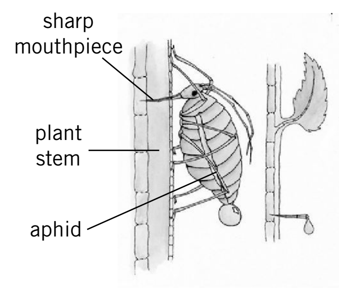
Plant diseases and insects

Plant diseases can also be directly caused by insects.

________ are insects that suck ______ from the stems of plants. This results in

-
-
-



Ladybirds can be used to control aphid infestations as ladybird ______ eat aphids.

Plant defences

Physical barriers

-
-
-

Chemical barriers

-
-

Mechanical adaptations

-
-
-

Controlling the spread of communicable disease

Give reasons why some factors can help prevent the spread of communicable diseases from one organism to another.

Hygiene	Isolation	Controlling ________	Vaccination
______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________

Key terms **Make sure you can write a definition for these key terms.**

aphid bacterium communicable disease fungicide fungus isolation mimic pathogen protist sexually transmitted disease (STD) toxin vaccination vector virus

Chapter 5: Communicable diseases

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B5 questions	Answers
1	What is a communicable disease?	
2	What is a pathogen?	
3	Name four types of pathogen.	
4	How can pathogens spread?	
5	How do bacteria make you ill?	
6	How do viruses make you ill?	
7	Name three examples of viral diseases.	
8	Name two examples of bacterial diseases.	
9	Name four methods of controlling the spread of communicable disease.	
10	Describe an example of a protist disease.	
11	Describe an example of a fungal disease in plants.	
12	How can the cause of a plant disease be identified?	
13	What are three mechanical defences that protect plants?	
14	Give three physical defences of plants.	
15	How can aphids be controlled by gardeners?	
16	How can plant diseases be detected?	

Chapter 6: Preventing and treating disease

Knowledge organiser

Non-specific defences

Non-specific defences of the human body against all pathogens include:

Skin

- physical barrier to infection
- produces antimicrobial secretions
- microorganisms that normally live on the skin prevent pathogens growing

Nose

Cilia and **mucus** trap particles in the air, preventing them from entering the lungs.

Trachea and bronchi produce mucus, which is moved away from the lungs to the back of the throat by cilia, where it is expelled.

Stomach

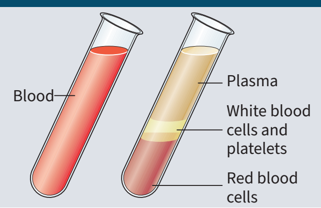
Produces strong acid (pH 2) that destroys pathogens in mucus, food, and drinks.

White blood cells

If a pathogen enters the body, the immune system tries to destroy the pathogen.

The function of **white blood cells** is to fight pathogens.

There are two main types of white blood cell – lymphocytes and phagocytes.



Lymphocytes

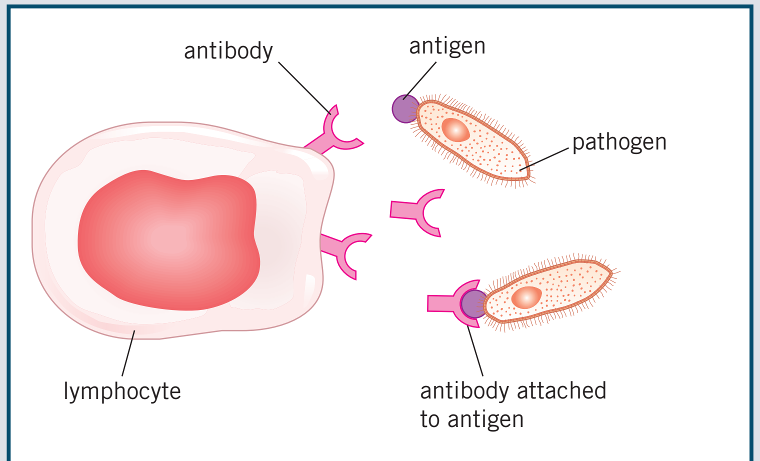
Lymphocytes fight pathogens in two ways:

Antitoxins

Lymphocytes produce **antitoxins** that bind to the toxins produced by some pathogens (usually bacteria). This *neutralises* the toxins.

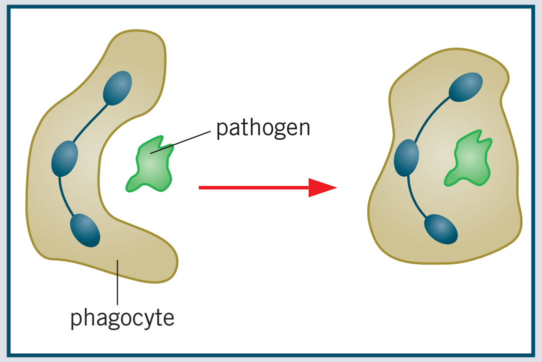
Antibodies

Lymphocytes produce **antibodies** that target and help to destroy specific pathogens by binding to **antigens** (proteins) on the pathogens' surfaces.



Phagocytes

1. Phagocytes are attracted to areas of infection.
2. The phagocyte surrounds the pathogen and engulfs it.
3. Enzymes that digest and destroy the pathogen are released.



Monoclonal antibodies (HT only)

Monoclonal antibodies are produced by mouse lymphocytes which are combined with a tumour cell to make a hybridoma cell. These can divide to make an antibody which can later be cloned and used to treat diseases such as cancer or used in pregnancy tests.

Key terms

Make sure you can write a definition for these key terms.

antibiotic, antibody, antigen, antitoxin, dose, double-blind trial, efficacy, Herd immunity, monoclonal antibodies, mucus, peer review, placebo, toxicity, vaccination, white blood cell

Treating diseases

Antibiotics

- **Antibiotics** are medicines that can kill *bacteria* in the body.
- Specific bacteria need to be treated by specific antibiotics.
- Antibiotics have greatly reduced deaths from infectious bacterial diseases, but antibiotic-resistant strains of bacteria are emerging.

Treating viral diseases

- Antibiotics *do not* affect viruses.
- Drugs that kill viruses often damage the body's tissues.
- Painkillers treat the symptoms of viral diseases but do not kill pathogens.

Discovering and developing new drugs

Drugs were traditionally extracted from plants and microorganisms, for example

- the heart drug digitalis comes from foxglove plants
- the painkiller aspirin originates from willow trees
- penicillin was discovered by Alexander Fleming from *Penicillium* mould.

Most modern drugs are now synthesised by chemists in laboratories.

New drugs are extensively tested and trialled for

- **toxicity** – is it harmful?
- **efficacy** – does it work?
- **dose** – what amount is safe and effective to give?

Stages of clinical trials

Pre-clinical trials

Drug is tested in cells, tissues, and live animals.

Clinical trials

1. Healthy volunteers receive very low doses to test whether the drug is safe and effective.
2. If safe, larger numbers of healthy volunteers and patients receive the drug to find the optimum dose.

Peer review

Before being published, the results of clinical trials will be tested and checked by independent researchers. This is called **peer review**.

Double-blind trials

Some clinical trials give some of their patients a **placebo** drug – one that is known to have no effect.

Double-blind trials are when neither the patients nor the doctors know who has been given the real drug and who has been given the placebo. This reduces biases in the trial.

Vaccinations

Vaccinations involve injecting small quantities of dead or inactive forms of a pathogen into the body. This stimulates lymphocytes to produce the correct antibodies for that pathogen. If the same pathogen re-enters the body, the correct antibodies can be produced quickly to prevent infection. If a large proportion of the population is vaccinated against a disease, it is less likely to spread. This is called **herd immunity**.

Chapter 6: Preventing and treating disease

Knowledge organiser

Non-specific defences

Non-specific defences of the human body against all pathogens include the skin, nose, and stomach. Give examples of how these can prevent disease.

Skin
-
-
-

Nose
-
-

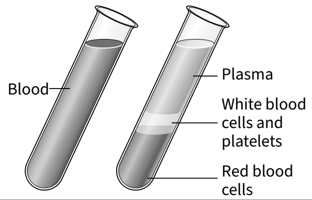
Stomach
-

White blood cells

If a pathogen enters the body, the ________ system tries to destroy the pathogen.

The function of **white blood cells** is to fight ________.

There are two main types of white blood cell – ________ and ________.



Lymphocytes

Lymphocytes fight pathogens in two ways:

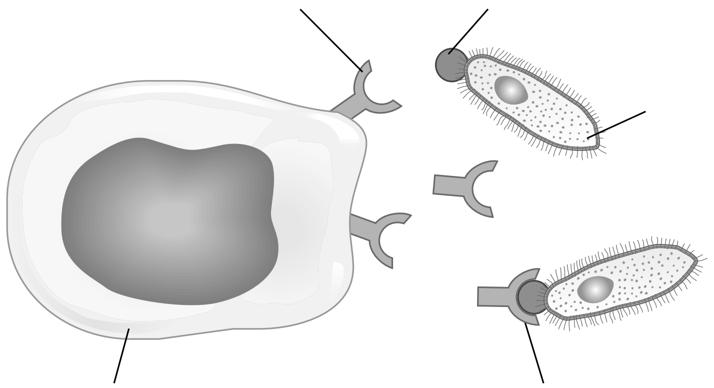
Antitoxins

Lymphocytes produce **antitoxins** that bind to the ________ produced by some pathogens (usually bacteria). This ________ the toxins.

Antibodies

Lymphocytes produce **antibodies** that target and help to destroy specific ________ by binding to ________ (proteins) on the pathogens' surfaces.

Label the diagram.

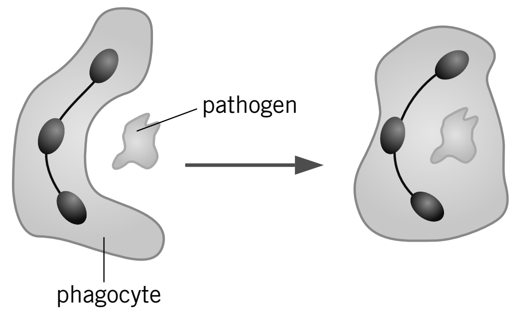


Phagocytes

1 Phagocytes are attracted to areas of ________.

2 The phagocyte surrounds the pathogen and ________ it.

3 ________ that digest and destroy the pathogen are released.



Monoclonal antibodies (HT only)

Monoclonal antibodies are produced by mouse lymphocytes which are combined with a tumour cell to make a ________ ________. These can divide to make an ________ which can later be cloned and used to treat diseases such as ________ or used in pregnancy tests.

Key terms

Make sure you can write a definition for these key terms.

antibiotic   antibody   antigen   antitoxin   dose   double-blind trial   efficacy   Herd immunity   monoclonal antibodies   mucus   peer review   placebo   toxicity   vaccination   white blood cell

Treating diseases

Antibiotics

- **Antibiotics** are medicines that can kill ________ in the body.
- Specific bacteria need to be treated by specific ________.
- Antibiotics have greatly ________ deaths from infectious bacterial diseases, but ________ - ________ strains of bacteria are emerging.

Treating viral diseases

- Antibiotics do not affect ________.
- Drugs that kill viruses often damage the body's ________.
- ________ treat the symptoms of viral diseases but do not kill pathogens.

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Drugs were traditionally extracted from ________ and ________, for example

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New drugs are extensively tested and trialled for

- ________ – is it harmful?
- ________ – does it work?
- ________ – what amount is safe and effective to give?

Stages of clinical trials

________ trials

Drug is tested in cells, tissues, and live animals.

Clinical trials

1 ________ volunteers receive very low doses to test whether the drug is ________ and ________.

2 If safe, larger numbers of healthy volunteers and patients receive the drug to find the ________ dose.

________ review

Before being published, the results of clinical trials will be tested and checked by independent researchers. This is called ________ **review**.

Double-blind trials

Some clinical trials give some of their patients a ________ drug – one that is known to have no effect.

Double-blind trials are ________ ________. This reduces ________ in the trial.

Vaccinations

Vaccinations involve injecting small quantities of ________ or ________ forms of a pathogen into the body. This stimulates ________ to produce the correct antibodies for that pathogen. If the same pathogen re-enters the body, the correct ________ can be produced quickly to prevent ________.

If a large proportion of the population is vaccinated against a disease, it is less likely to spread. This is called ________ ________.

Chapter 6: Preventing and treating disease

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B6 questions	Answers
1	What non-specific systems does the body use to prevent pathogens getting into it?	• • •
2	What three functions do white blood cells have?	
3	What happens during phagocytosis?	
4	What are antigens?	
5	Why are antibodies a specific defence?	
6	What is the function of an antitoxin?	
7	What does a vaccine contain?	
8	How does vaccination protect against a specific pathogen?	
9	What is herd immunity?	
10	What is an antibiotic?	
11	What do painkillers do?	
12	What properties of new drugs are clinical trials designed to test?	
13	What happens in the pre-clinical stage of a drug trial?	
14	What is a placebo?	
15	What is a double-blind trial?	
16	What is a monoclonal antibody?	
17	Give two examples in which monoclonal antibodies can be used for.	

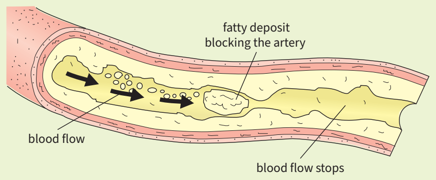
Chapter 7: Non-communicable diseases

Knowledge organiser

Coronary heart disease

Coronary heart disease (CHD) occurs when the coronary arteries become narrowed by the build-up of layers of fatty material within them.

This reduces the flow of blood, resulting in less oxygen for the heart muscle, which can lead to heart attacks.



Health issues

Health is the state of physical and mental well-being.

The following factors can affect health:

- communicable and non-communicable diseases
- diet
- stress
- exercise
- life situations.

Different types of disease may interact, for example:

- defects in the immune system make an individual more likely to suffer from infectious diseases
- viral infection can trigger cancers
- immune reactions initially caused by a pathogen can trigger allergies, for example skin rashes and asthma
- severe physical ill health can lead to depression and other mental illnesses.

Treating cardiovascular diseases

Treatment	Description	Advantages	Disadvantages
stent	inserted into blocked coronary arteries to keep them open	• widens the artery – allows more blood to flow, so more oxygen is supplied to the heart • less serious surgery	• can involve major surgery – risk of infection, blood loss, blood clots, and damage to blood vessels • risks from anaesthetic used during surgery
statins	drugs that reduce blood **cholesterol** levels, slowing down the deposit of fatty material in the arteries	• effective • no need for surgery • can prevent CHD from developing	• possible side effects such as muscle pain, headaches, and sickness • cannot cure CHD, so patient will have to take tablets for many years
replace faulty heart valves	heart valves that leak or do not open fully, preventing control of blood flow through the heart, can be replaced with biological or mechanical valves	• allows control of blood flow through the heart • long-term cure for faulty heart valves	• can involve major surgery – risk of infection, blood loss, blood clots, and damage to blood vessels • risks from anaesthetic used during surgery
transplants	if the heart fails a donor heart, or heart and lungs, can be transplanted **artificial hearts** can be used to keep patients alive whilst waiting for a heart transplant, or to allow the heart to rest during recovery	• long-term cure for the most serious heart conditions • treats problems that cannot be treated in other ways	• transplant may be rejected if there is not a match between donor and patient • lengthy process • major surgery – risk of infection, blood loss, blood clots, and damage to blood vessels • risks from anaesthetic used during surgery

Risk factors and non-communicable diseases

A **risk factor** is any aspect of your lifestyle or substance in your body that can increase the risk of a disease developing.

Some risk factors cause specific diseases. Other diseases are caused by factors interacting.

Risk factor	Disease	Effects of risk factor
diet (obesity) and amount of exercise	Type 2 diabetes	body does not respond properly to the production of insulin, so blood glucose levels cannot be controlled
	cardiovascular diseases	increased blood cholesterol can lead to CHD
alcohol	impaired liver function	long-term alcohol use causes liver cirrhosis (scarring), meaning the liver cannot remove toxins from the body or produce sufficient bile
	impaired brain function	damages the brain and can cause anxiety and depression
	affected development of unborn babies	alcohol can pass through the placenta, risking miscarriages, premature births, and birth defects
smoking	lung disease and cancers	cigarettes contain carcinogens, which can cause cancers
	affected development of unborn babies	chemicals can pass through the placenta, risking premature births and birth defects
carcinogens, such as ionising radiation, and genetic risk factors	cancers	for example, tar in cigarettes and ultraviolet rays from the Sun can cause cancers
		some genetic factors make an individual more likely to develop certain cancers

Cancer

Cancer is the result of changes in cells that lead to uncontrolled growth and division by mitosis.

Rapid division of abnormal cells can form a **tumour**.

Malignant tumours are cancerous tumours that invade neighbouring tissues and spread to other parts of the body in the blood, forming secondary tumours.

Benign tumours are non-cancerous tumours that do not spread in the body.

Treatment

Treatment of non-communicable diseases linked to lifestyle risk factors – such as poor diet, drinking alcohol, and smoking – can be very costly, both to individuals and to the Government.

A high incidence of these lifestyle risk factors can cause high rates of non-communicable diseases in a population.

Key terms

Make sure you can write a definition for these key terms.

artificial heart   benign   carcinogen   cholesterol   coronary heart disease
health   malignant   risk factor   statin   stent   transplant   tumour

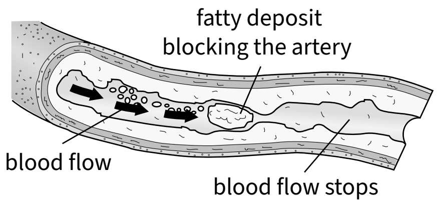
Chapter 7: Non-communicable diseases

Knowledge organiser

Coronary heart disease

Coronary heart disease (CHD) occurs when the coronary arteries become ________ by the build-up of layers of ________ material within them.

This reduces the flow of ________, resulting in less ________ for the heart muscle, which can lead to ________ ________.



Health issues

Health is the state of physical and mental well-being.

The following factors can affect health:

-
-
-
-
-

Different types of disease may interact, for example:

- ________ in the immune system make an individual more likely to suffer from infectious diseases
- ________ infection can trigger cancers
- immune reactions initially caused by a ________ can trigger allergies, for example skin rashes and asthma
- severe physical ill health can lead to ________ and other mental illnesses.

Treating cardiovascular diseases

Treatment	Description	Advantages	Disadvantages
stent	inserted into ________ coronary arteries to keep them open	• •	• •
statins	drugs that reduce blood ________ levels, slowing down the deposit of ________ material in the arteries	• • •	• • •
replace faulty heart valves	heart valves that ________ or do not open fully, preventing control of blood flow through the heart, can be replaced with ________ or ________ valves	• •	• •
transplants	if the heart ________ a donor heart, or heart and lungs, can be transplanted ________ ________ can be used to keep patients alive whilst waiting for a heart transplant, or to allow the heart to rest during recovery	• •	• • • •

Risk factors and non-communicable diseases

A **risk factor** is any aspect of your lifestyle or substance in your body that can ________ the risk of a disease developing.

Some risk factors cause specific diseases. Other diseases are caused by factors interacting.

Risk factor	Disease	Effects of risk factor
diet (obesity) and amount of exercise	•	
	•	
alcohol	•	
	•	
	•	
smoking	•	
	•	
carcinogens, such as ionising radiation, and genetic risk factors	•	

Cancer

Cancer is the result of changes in cells that lead to ________ growth and division by ________.

Rapid division of abnormal cells can form a ________.

________ tumours are cancerous tumours that invade neighbouring tissues and spread to other parts of the body in the blood, forming ________ tumours.

________ tumours are non-cancerous tumours that do not spread in the body.

Treatment

Treatment of non-communicable diseases can be very costly to both individuals and the Government. They are often caused by lifestyle risk factors including:

-
-
-

A high incidence of these lifestyle risk factors can cause high rates of non-communicable diseases in a ________.

Key terms

Make sure you can write a definition for these key terms.

artificial heart, benign, carcinogen, cholesterol, coronary heart disease, health, malignant, risk factor, statin, stent, transplant, tumour

Chapter 7: Non-communicable diseases

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B7 questions	Answers
1	What is coronary heart disease?	
2	What is a stent?	
3	What are statins?	
4	What is a faulty heart valve?	
5	How can a faulty heart valve be treated?	
6	When do heart transplants take place?	
7	What are artificial hearts used for?	
8	Define health.	
9	What factors can affect health?	
10	What is a risk factor?	
11	Give five risk factors.	
12	What is cancer?	
13	What are malignant tumours?	
14	What are benign tumours?	
15	What two types of risk factor affect the development of cancers?	
16	What is a carcinogen?	

Chapter 8: Photosynthesis

Knowledge organiser

Photosynthetic reaction

Photosynthesis is a chemical reaction in which energy is transferred from the environment as light from the Sun to the leaves of a plant. This is an **endothermic** reaction.

Chlorophyll, the green pigment in **chloroplasts** in the leaves, absorbs the light energy. Leaves are well-adapted to increase the rate of photosynthesis when needed.

Rate of photosynthesis

A **limiting factor** is anything that limits the rate of a reaction when it is in short supply.

The limiting factors for photosynthesis are

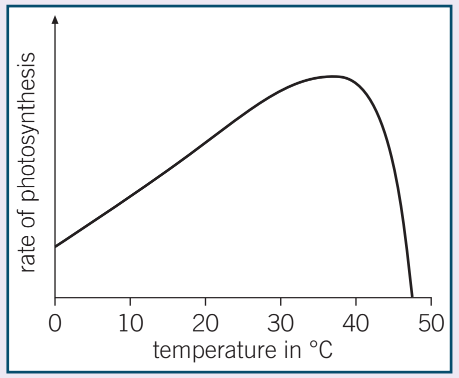
- temperature
- light intensity
- carbon dioxide concentration
- amount of chlorophyll.

Less chlorophyll in the leaves reduces the rate of photosynthesis. More chlorophyll may be produced by plants in well-lit areas to increase the photosynthesis rate.

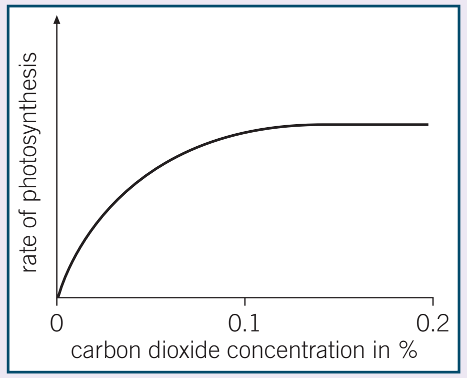
L **carbon dioxide** + water $\xrightarrow{\text{light}}$ **glucose** + oxygen

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

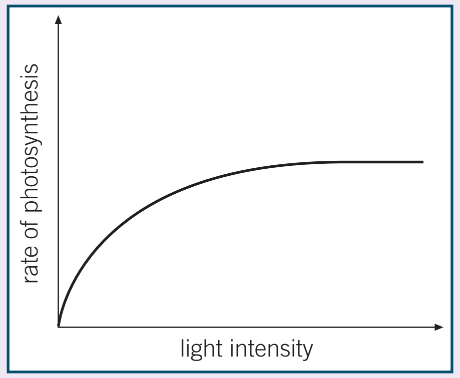
Limiting factors and photosynthesis rate (HT only)



- At low temperatures the rate of photosynthesis is low because the reactant molecules have less kinetic energy.
- Photosynthesis is an enzyme-controlled reaction, so at high temperatures the enzymes are denatured and the rate quickly decreases.



- Carbon dioxide is used up in photosynthesis, so increasing carbon dioxide concentration increases the rate of photosynthesis.
- At a certain point, another factor becomes limiting.
- Carbon dioxide is often the limiting factor for photosynthesis.

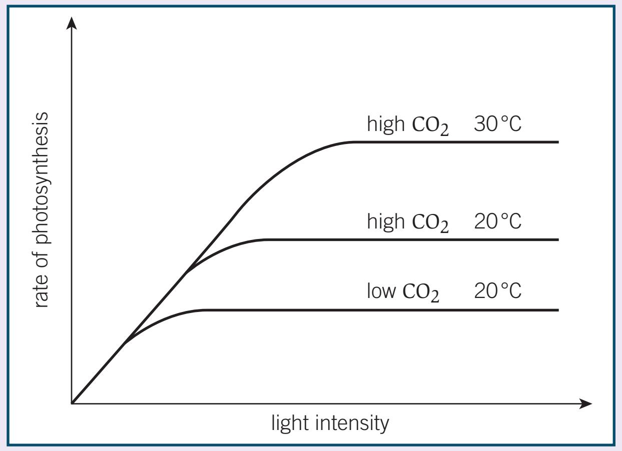


- Light energy is needed for photosynthesis, so increasing light intensity increases the rate of photosynthesis.
- At a certain point, another factor becomes limiting.
- Photosynthesis will stop if there is little or no light.

Interaction of limiting factors (HT only)

Limiting factors often interact, and any one may be limiting photosynthesis.

For example, on the graph the lowest curve has both carbon dioxide and temperature limiting photosynthesis. Temperature is limiting for the middle curve, and the highest curve shows photosynthesis rate increases when both temperature and carbon dioxide are increased until another factor becomes limiting.



Inverse square law (HT only)

As the distance of a light source from a plant increases, the light intensity decreases – this is called an inverse relationship. This relationship is not linear, as light intensity varies in inverse proportion to the square of the distance:

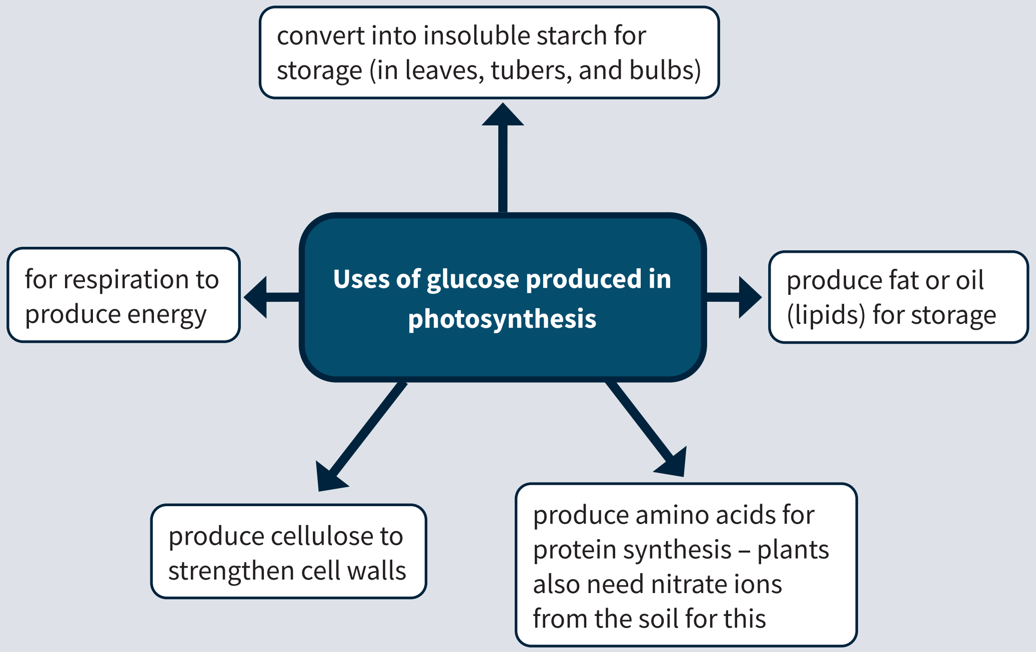
L $$\text{light intensity} \propto \frac{1}{\text{distance}^2}$$

For example, if you double the distance between a light source and a plant, light intensity falls by three-quarters.

Greenhouse economics

Commercial greenhouses control limiting factors to get the highest possible rates of photosynthesis so they can grow plants as quickly as possible or produce the highest yields, whilst still making a profit.

Uses of glucose



Key terms

Make sure you can write a definition for these key terms.

carbon dioxide · chlorophyll · chloroplast · concentration · endothermic · glucose · greenhouse gases · light intensity · inverse square law · limiting factor · photosynthesis · protein synthesis

Chapter 8: Photosynthesis

Knowledge organiser

Photosynthetic reaction

Photosynthesis is a chemical reaction in which energy is transferred from the environment as ______ from the Sun to the ______ of a plant. This is an ______ reaction.

Chlorophyll, the green pigment in ______ in the leaves, ______ the light energy. Leaves are well-adapted to ______ the rate of photosynthesis when needed.

(L) ______ + ______ → ______ + ______

$\_CO_2 + \_H_2O \rightarrow C_6H_{12}O_6 + \_O_2$

Rate of photosynthesis

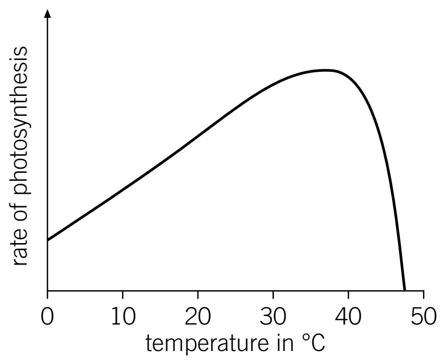
A ______ ______ is anything that limits the rate of a reaction when it is in short supply.

The limiting factors for photosynthesis are

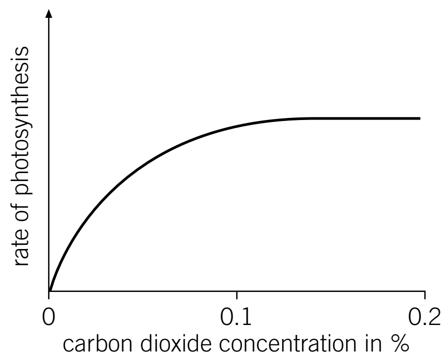
-
-
-
-

Less chlorophyll in the leaves ______ the rate of photosynthesis. More chlorophyll may be produced by plants in well-lit areas to ______ the photosynthesis rate.

Limiting factors and photosynthesis rate (HT only)



- At low temperatures the rate of photosynthesis is ______ because the reactant molecules have less ______ energy.
- Photosynthesis is an enzyme-controlled reaction, so at high temperatures the enzymes are ______ and the rate quickly ______.



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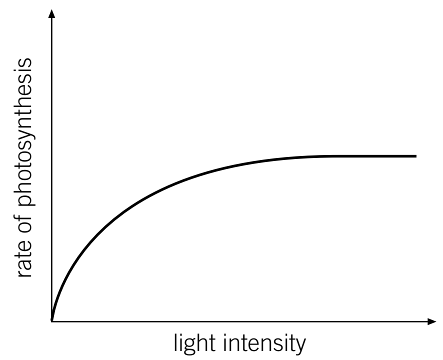

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- At a certain point, another factor becomes limiting.
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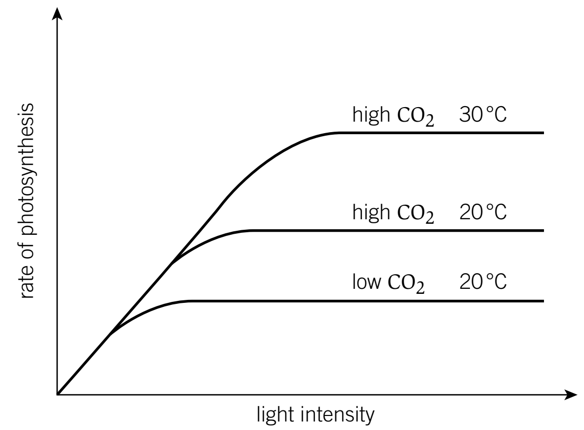
Limiting factors often interact, and any one may be limiting photosynthesis.

For example, on the graph the ______ curve has both carbon dioxide and temperature limiting photosynthesis. ______ is limiting for the middle curve, and the highest curve shows photosynthesis rate increases when both ______ and ______ ______ are increased until another factor becomes limiting.



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As the distance of a light source from a plant ______, the light intensity ______ – this is called an inverse relationship. This relationship is not ______, as light intensity varies in inverse proportion to the square of the distance:

(L) ______ $\propto$ ______

For example, if you ______ the distance between a light source and a plant, light intensity falls by three-quarters.

Greenhouse economics

Commercial greenhouses ______ limiting factors to get the highest possible rates of ______ so they can grow plants as quickly as possible or produce the highest ______, whilst still making a profit.

Uses of glucose

Uses of glucose produced in photosynthesis

- convert into ______ starch for storage (in leaves, tubers, and bulbs)
- produce fat or oil (______) for ______
- produce ______ ______ for ______ ______ – plants also need ______ ions from the soil for this
- produce ______ to strengthen ______ ______
- for ______ to produce ______

Key terms

Make sure you can write a definition for these key terms.

carbon dioxide · *chlorophyll* · *chloroplast* · *concentration* · *endothermic* · *glucose* · *greenhouse gases* · *light intensity* · *inverse square law* · *limiting factor* · *photosynthesis* · *protein synthesis*

Chapter 8: Photosynthesis

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B8 questions	Answers
1	Where does photosynthesis occur?	
2	What is the name of the green pigment in the leaves?	
3	What type of reaction is photosynthesis?	
4	What type of energy is used in photosynthesis?	
5	Give the word equation for photosynthesis.	
6	Give the balanced symbol equation for photosynthesis.	
7	Define the term limiting factor.	
8	Give the limiting factors of photosynthesis.	• • • •
9	Describe how light intensity affects the rate of photosynthesis.	
10	Describe how carbon dioxide concentration affects the rate of photosynthesis.	
11	Describe how temperature affects the rate of photosynthesis.	
12	Give the equation for the inverse square law for light intensity.	
13	Why are limiting factors important in the economics of growing plants in greenhouses?	
14	How do plants use the glucose produced in photosynthesis?	• • • • •

Chapter 9: Respiration

Knowledge organiser

Cellular respiration

Cellular **respiration** is an **exothermic** reaction that occurs continuously in the **mitochondria** of living cells to supply the cells with energy.

The energy released during respiration is needed for all living processes, including

- chemical reactions to build larger molecules, for example, making proteins from amino acids
- muscle contraction for movement
- keeping warm.

Respiration in cells can take place aerobically (using oxygen) or anaerobically (without oxygen).

Type of respiration	Oxygen required?	Relative amount of energy transferred
aerobic	✓	complete **oxidation** of glucose – large amount of energy is released
anaerobic	✗	incomplete oxidation of glucose – much less energy is released per glucose molecule than in aerobic respiration

Aerobic respiration

glucose + oxygen → carbon dioxide + water

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Anaerobic respiration in muscles

glucose → lactic acid

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$$

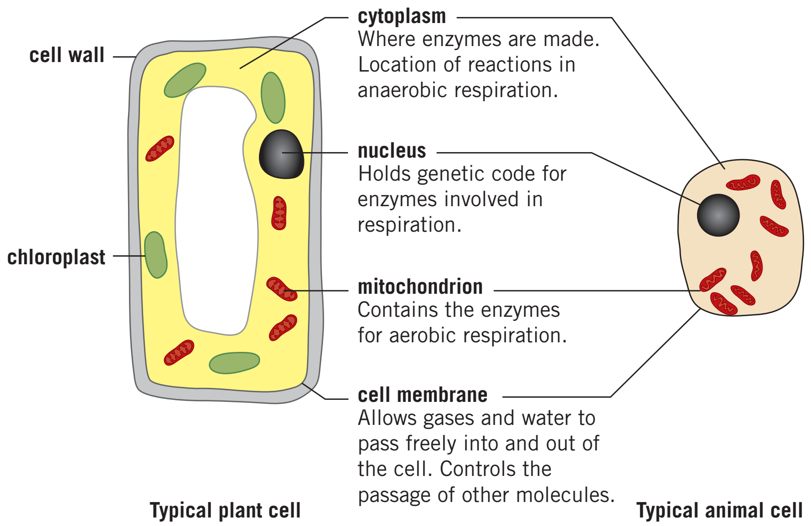
Fermentation

Anaerobic respiration in plant and yeast cells is represented by the equation

glucose → ethanol + carbon dioxide

Anaerobic respiration in yeast cells is called **fermentation**.

The products of fermentation are important in the manufacturing of bread and alcoholic drinks.



Typical plant cell

Typical animal cell

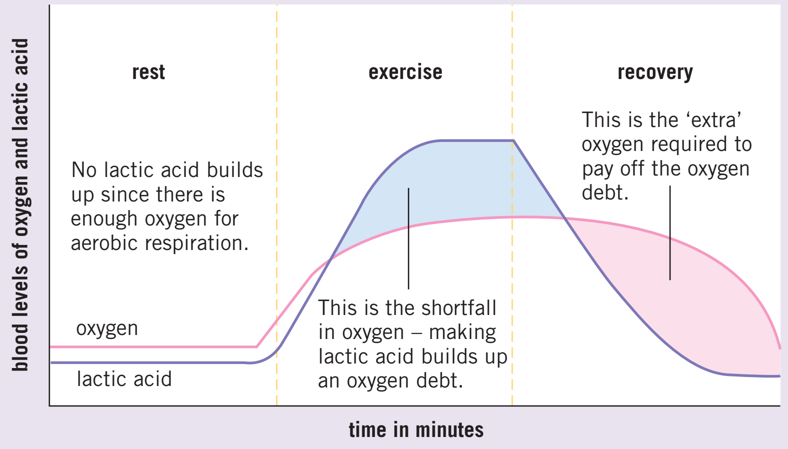
Response to exercise

During exercise the human body reacts to the increased demand for energy.

To supply the muscles with more oxygenated blood, heart rate, breathing rate, and breath volume all increase.

If insufficient oxygen is supplied, anaerobic respiration takes place instead, leading to the build-up of **lactic acid**.

During long periods of vigorous exercise, muscles become fatigued and stop contracting efficiently.



Oxygen debt (HT only)

After exercise, the lactic acid accumulated during anaerobic respiration needs to be removed.

Oxygen debt is the amount of oxygen needed to react with the lactic acid to remove it from cells.

Removal of lactic acid

lactic acid in the muscles

↓

transported to the liver in the blood

↓

lactic acid is converted back to glucose

Metabolism

Metabolism is the sum of all the reactions in a cell or the body.

The energy released by respiration in cells is used for the continual enzyme-controlled processes of metabolism that produce new molecules.

Metabolic processes include the synthesis and breakdown of:

Carbohydrates

- synthesis of larger carbohydrates from sugars (starch, glycogen, and cellulose)
- breakdown of glucose in respiration to release energy

Lipids

- synthesis of lipids from one molecule of glycerol and three molecules of fatty acid

Proteins

- synthesis of amino acids from glucose and nitrate ions
- amino acids used to form proteins
- excess proteins broken down to form urea for excretion

Key terms

Make sure you can write a definition for these key terms.

aerobic   amino acids   anaerobic   carbohydrates   cellulose   exothermic   fermentation
fatty acid   glycerol   glycogen   lactic acid   lipids   metabolism   mitochondria
oxidation   oxygen debt   proteins   respiration   starch

Chapter 9: Respiration

Knowledge organiser

Cellular respiration

Cellular **respiration** is an ______ reaction that occurs continuously in the ______ of living cells to supply the cells with energy.

The energy released during respiration is needed for all living processes, including

-
-
-

Respiration in cells can take place ______ (using oxygen) or ______ (without oxygen).

Type of respiration	Oxygen required?	Relative amount of energy transferred
aerobic	______	complete ______ of glucose – large amount of ______ is released
anaerobic	______	______ oxidation of glucose – much ______ energy is released per glucose molecule than in aerobic respiration

Aerobic respiration

______ + ______ → ______ + ______

$C_6H_{12}O_6$ + _O_2 → _CO_2 + _H_2O

Anaerobic respiration in muscles

______ → ______

$C_6H_{12}O_6$ → _$C_3H_6O_3$

Fermentation

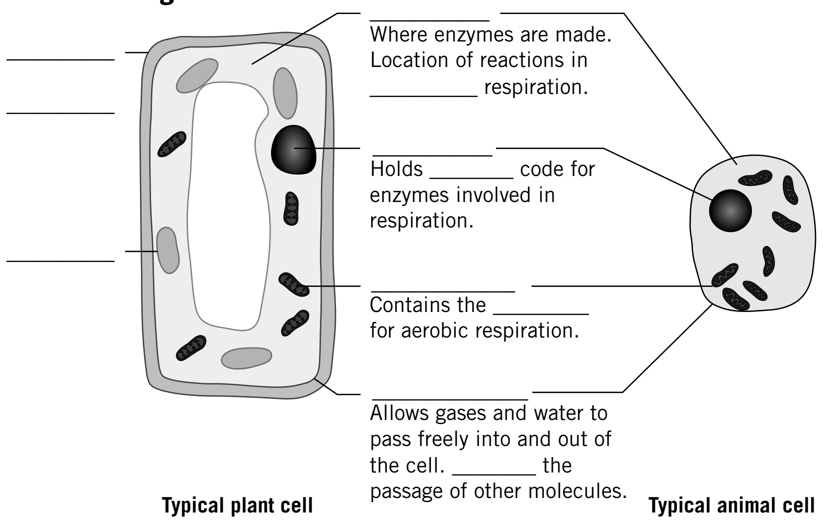
Anaerobic respiration in plant and ______ cells is represented by the equation

______ → ______ + ______ ______

Anaerobic respiration in yeast cells is called ______.

The products of fermentation are important in the manufacturing of ______ and ______.

Label the diagram.



Key terms

Make sure you can write a definition for these key terms.

aerobic, amino acids, anaerobic, carbohydrates, cellulose, exothermic, fermentation, fatty acid, glycerol, glycogen, lactic acid, lipids, metabolism, mitochondria, oxidation, oxygen debt, proteins, respiration, starch

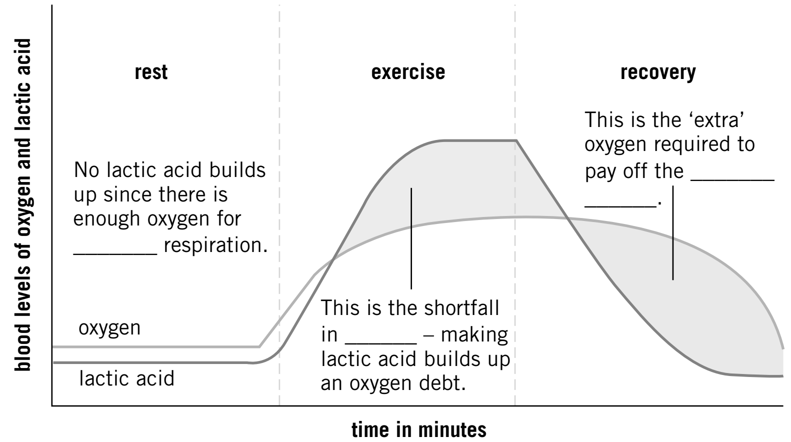
Response to exercise

During exercise the human body ______ to the increased demand for energy.

To supply the muscles with more ______ blood, ______ rate, ______ rate, and breath ______ all increase.

If insufficient oxygen is supplied, ______ respiration takes place instead, leading to the build-up of ______ ______.

During long periods of vigorous exercise, ______ become fatigued and stop contracting efficiently.



Oxygen debt (HT only)

After exercise, the lactic acid accumulated during anaerobic respiration needs to be ______.

Oxygen debt is the amount of oxygen needed to react with the lactic acid to remove it from ______.

Removal of lactic acid

lactic acid in the ______

↓

transported to the ______ in the blood

↓

lactic acid is converted back to ______

Metabolism

Metabolism is the ______ of all the reactions in a cell or the body.

The energy released by ______ in cells is used for the continual enzyme-controlled processes of ______ that produce new molecules.

Metabolic processes include the synthesis and breakdown of:

Carbohydrates

- synthesis of larger ______ from ______ (starch, glycogen, and cellulose)
- breakdown of glucose in respiration to release energy

Proteins

- synthesis of ______ ______ from ______ and ______ ions
- amino acids used to form ______
- excess proteins broken down to form ______ for excretion

Lipids

- synthesis of ______ from one molecule of ______ and three molecules of ______ ______

Chapter 9: Respiration

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	B9 questions	Answers
1	Define the term cellular respiration.	
2	What do organisms need energy for?	• • •
3	What is the difference between aerobic and anaerobic respiration?	
4	Write the word equation for aerobic respiration.	
5	Write the word equation for anaerobic respiration in muscles.	
6	Write the balanced symbol equation for aerobic respiration.	
7	Why does aerobic respiration release more energy per glucose molecule than anaerobic respiration?	
8	What is anaerobic respiration in yeast cells called?	
9	Write the word equation for anaerobic respiration in plant and yeast cells.	
10	How does the body supply the muscles with more oxygenated blood during exercise?	
11	What substance builds up in the muscles during anaerobic respiration?	
12	What happens to muscles during long periods of activity?	
13	What is oxygen debt?	
14	How is lactic acid removed from the body?	
15	What is metabolism?	

Chapter 1: Conservation and dissipation of energy

Knowledge organiser

Systems

A **system** is an object or group of objects.

Whenever anything changes in a system, energy is transferred between its stores or to the surroundings.

A **closed system** is one where no energy can escape to or enter from the surroundings. The total energy in a closed system never changes.

Energy stores

kinetic	energy an object has because it is moving
gravitational potential	energy an object has because of its height above the ground
elastic potential	energy an elastic object has when it is stretched or compressed
thermal (or internal)	energy an object has because of its temperature (the total kinetic and potential energy of the particles in the object)
chemical	energy that can be transferred by chemical reactions involving foods, fuels, and the chemicals in batteries
nuclear	energy stored in the nucleus of an atom
magnetic	energy a magnetic object has when it is near a magnet or in a magnetic field
electrostatic	energy a charged object has when near another charged object

Energy transfers

Energy can be transferred to and from different stores by:

Heating
Energy is transferred from one object to another object with a lower temperature.

Waves
Waves (e.g., light and sound) can transfer energy.

Electricity
An electric current transfers energy.

Forces (mechanical work)
Energy is transferred when a force moves or changes the shape of an object.

Examples of energy transfers

When you stretch a rubber band, energy from your chemical store is mechanically transferred to the rubber band's elastic potential store.

When a block is dropped from a height, energy is mechanically transferred (by the force of gravity) from the block's gravitational potential store to its kinetic store.

When this block hits the ground, energy from its kinetic energy store is transferred mechanically and by sound waves to the thermal energy store of the surroundings.

The electric current in a kettle transfers energy to the heating element's thermal energy store. Energy is then transferred by heating from the heating element's thermal energy store to the thermal energy store of the water.

When an object slows down due to friction, energy is mechanically transferred from the object's kinetic store to its thermal store, the thermal store of the object it is rubbing against, and to the surroundings.

Work done

When an object is moved by a force **work** is done on the object. The force transfers energy to the object. The amount of energy transferred is equal to the work done. You can calculate the work done (and the energy transferred) using the equation:

(L) work done (J) = force (N) x distance moved along the line of action of the force (m)

Calculating the energy in an energy store

An object's gravitational potential energy store depends on its height above the ground, the gravitational field strength, and its mass.

gravitational potential energy (J) = mass (kg) × gravitational field strength (N/kg) × height (m)

(L) $E_p = m\,g\,h$

An object's kinetic energy store depends only on its mass and speed.

kinetic energy (J) = 0.5 × mass (kg) × (speed)^2 (m/s)

(L) $E_k = \frac{1}{2} m\,v^2$

The elastic potential energy store of a stretched spring can be calculated using:

elastic potential energy (J) = 0.5 × spring constant (N/m) × (extension)^2 (m)

$E_e = \frac{1}{2} k\,e^2$ (assuming the limit of proportionality has not been exceeded)

Power is how much work is done (or how much energy is transferred) per second. The unit of power is the watt (W).

1 watt = 1 joule of energy transferred per second

$$\text{power (W)} = \frac{\text{energy transferred (J)}}{\text{time (s)}}$$

(L) $P = \frac{E}{t}$

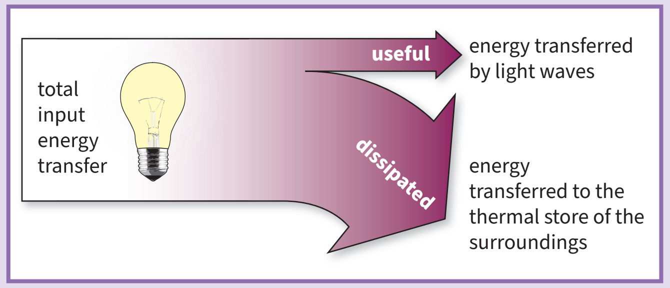
or

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time (s)}}$$

$P = \frac{W}{t}$

Useful and dissipated energy

Energy cannot be created or destroyed – it can only be transferred usefully, stored, or dissipated (wasted).



Energy is never entirely transferred usefully – some energy is always dissipated, meaning it is transferred to less useful stores.

All energy eventually ends up transferred to the thermal energy store of the surroundings.

In machines, work done against the force of friction usually causes energy to be wasted because energy is transferred to the thermal store of the machine and its surroundings.

Lubrication is a way of reducing unwanted energy transfer due to friction.

Streamlining is a way of reducing energy wasted due to air resistance or drag in water.

Use of thermal insulation is a way of reducing energy wasted due to heat dissipated to the surroundings.

Efficiency is a measure of how much energy is transferred usefully. You must know the equation to calculate efficiency as a *decimal*:

$$\text{efficiency} = \frac{\text{useful output energy transfer (J)}}{\text{total input energy transfer (J)}}$$

(L) *or*

$$\text{efficiency} = \frac{\text{useful power output (W)}}{\text{total power input (W)}}$$

To give efficiency as a *percentage*, just multiply the result from the above calculation by 100 and add the % sign to the answer.

Key terms

Make sure you can write a definition for these key terms.

chemical, closed system, dissipated, efficiency, elastic potential, electrostatic, gravitational potential, kinetic, lubrication, magnetic, nuclear, power, streamlining, system, thermal, work done

Chapter 1: Conservation and dissipation of energy

Knowledge organiser

Systems

A **system** is an ________ or group of objects.

Whenever anything changes in a system, ________ is transferred between its stores or to the surroundings.

A ________ ________ is one where no energy can escape to or enter from the surroundings. The total energy in a closed system ________ changes.

Energy stores

kinetic	energy an object has because it is ________
________ ________	energy an object has because of its height above the ground
elastic potential	energy an elastic object has when it is stretched or ________
thermal (or internal)	energy an object has because of its ________ (the total kinetic and potential energy of the particles in the object)
________	energy that can be transferred by chemical reactions involving foods, fuels, and the chemicals in batteries
________	energy stored in the nucleus of an atom
magnetic	energy a magnetic object has when it is near a magnet or in a magnetic ________
________	energy a charged object has when near another charged object

Energy transfers

Energy can be transferred to and from different stores by:

Heating
Energy is transferred from one object to another object with a ________ temperature.

Waves
Waves (e.g., ________ and ________) can transfer energy.

Electricity
An electric ________ transfers energy.

Forces (mechanical work)
Energy is transferred when a force moves or changes the ________ of an object.

Examples of energy transfers

When you stretch a rubber band, energy from your chemical store is ________ transferred to the rubber band's ________ ________ store.

When a block is dropped from a height, energy is mechanically transferred (by the force of gravity) from the block's ________ ________ store to its ________ store.

When this block hits the ground, energy from its ________ ________ store is transferred mechanically and by ________ waves to the ________ energy store of the surroundings.

The electric current in a ________ transfers energy to the heating element's thermal energy store. Energy is then transferred by heating from the heating element's thermal energy store to the thermal energy store of the water.

When an object slows down due to ________, energy is mechanically transferred from the object's kinetic store to its thermal store, the thermal store of the object it is ________ against, and to the surroundings.

Work done

When an object is moved by a ________ **work** is done on the object. The force transfers energy to the ________. The amount of energy transferred is ________ to the work done. You can calculate the work done (and the energy transferred) using the equation:

(L) work done (J) = ________ (N) x ________ (m)

Calculating the energy in an energy store

An object's gravitational potential energy store depends on its height above the ground, the gravitational field strength, and its mass.

gravitational potential energy (J) = ________ (kg) × ________ ________ (N/kg) × ________ (m)

(L) $E_p = m\,g\,h$

An object's kinetic energy store depends only on its mass and speed.

kinetic energy (J) = ________ × ________ (kg) × (________)^2 (m/s)

(L) $E_k = \frac{1}{2} m\,v^2$

The elastic potential energy store of a stretched spring can be calculated using:

elastic potential energy (J) = ________ × ________ ________ (N/m) × (________)^2 (m)

$E_e = \frac{1}{2} k\,e^2$ (assuming the limit of proportionality has not been exceeded)

Power is how much work is done (or how much energy is transferred) per second. The unit of power is the watt (W).

1 watt = 1 joule of energy transferred per second

power (W) = ________ (J) / ________ (s)

(L) $P = \frac{E}{t}$

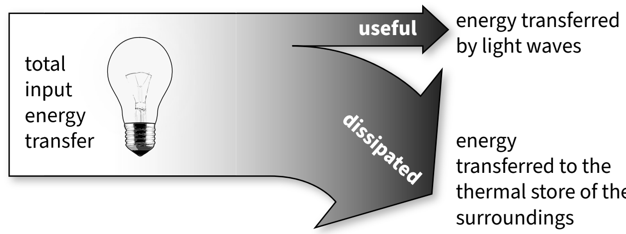
or

power (W) = ________ (J) / ________ (s)

$P = \frac{W}{t}$

Useful and dissipated energy

Energy cannot be ________ or destroyed – it can only be transferred usefully, stored, or dissipated (wasted).



Energy is never entirely ________ usefully – some energy is always dissipated, meaning it is transferred to less ________ stores.

All energy eventually ends up transferred to the ________ energy store of the surroundings.

In machines, work done against the force of ________ usually causes energy to be wasted because energy is transferred to the thermal store of the machine and its ________.

________ is a way of reducing unwanted energy transfer due to friction.

________ is a way of reducing energy wasted due to air resistance or drag in water.

Use of thermal ________ is a way of reducing energy wasted due to heat dissipated to the surroundings.

________ is a measure of how much energy is transferred usefully. You must know the equation to calculate efficiency as a *decimal*:

(L) efficiency = ________ (J) / ________ (J)

or

efficiency = ________ (W) / ________ (W)

To give efficiency as a *percentage*, just multiply the result from the above calculation by ______ and add the % sign to the answer.

Key terms

Make sure you can write a definition for these key terms.

chemical, closed system, dissipated, efficiency, elastic potential, electrostatic, gravitational potential, kinetic, lubrication, magnetic, nuclear, power, streamlining, system, thermal, work done

Chapter 1: Conservation and dissipation of energy

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P1 questions	Answers
1	Name the five energy stores	
2	Name the four ways in which energy can be transferred.	
3	What is a system?	
4	What is a closed system?	
5	What is work done?	
6	What is the unit for energy?	
7	What is one joule of work?	
8	Describe the energy transfer when a moving car slows down.	
9	Describe the energy transfer when an electric kettle is used to heat water.	
10	Describe the energy transfer when a ball is fired using an elastic band.	
11	Describe the energy transfer when a battery powered toy car is used.	
12	Describe the energy transfer when a falling apple hits the ground.	
13	Name the unit that represents one joule transferred per second.	
14	A motor is 30% efficient. What does that mean?	

Chapter 2: Energy transfer by heating

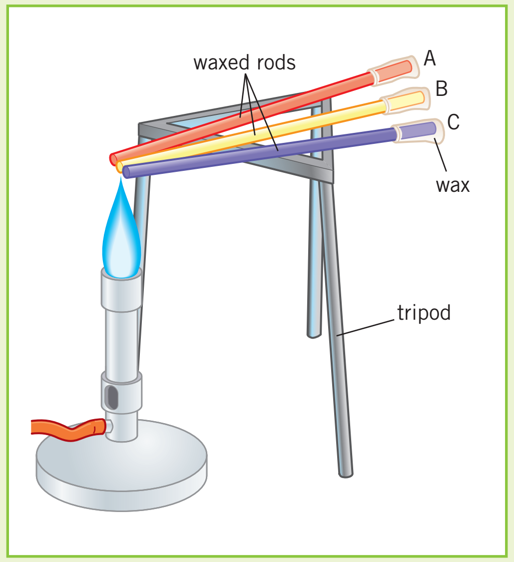
Knowledge organiser

Thermal conductivity

The **thermal conductivity** of a material tells you how quickly energy is transmitted through it by thermal conduction.

You can test the thermal conductivity of rods made of different metals using this experimental set-up. Each rod must have the same diameter and length, and the same temperature difference between its ends.

One end of each rod is covered in wax and the other ends are heated equally. The faster the wax melts, the higher the thermal conductivity of the metal.



Insulating buildings

Heating bills can be expensive so it is important to reduce the rate of heat loss from buildings.

Some factors that affect the rate of heat loss from a building include:

1. the thickness of its walls and roof
2. the thermal conductivity of its walls and roof.

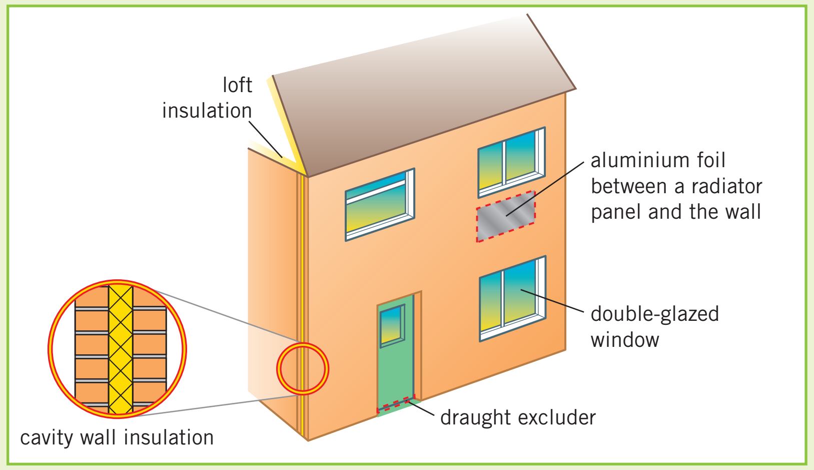
lower thermal conductivity = lower rate of heat loss

The thermal conductivity of the walls and roof can be reduced by using **thermal insulators**.

A thermal insulator is a material which has a low thermal conductivity. The rate of energy transfer through an insulator is low.

The energy transfer per second through a material depends on:

1. the material's thermal conductivity
2. the temperature difference between the two sides of the material
3. the thickness of the material.



Infrared radiation

Infrared radiation is part of the **electromagnetic spectrum**.

All objects **emit** (give out) and **absorb** (take in) infrared radiation.

The higher the temperature of an object, the more infrared radiation it emits in a given time.

A good absorber of infrared radiation is also a good emitter.

For an object at a constant temperature:

- infrared radiation emitted = infrared radiation absorbed
- infrared radiation is emitted across a continuous range of wavelengths.

An object's temperature will increase if it absorbs infrared radiation at a higher rate than it emits it. This rule applies to the planet Earth.

Black bodies

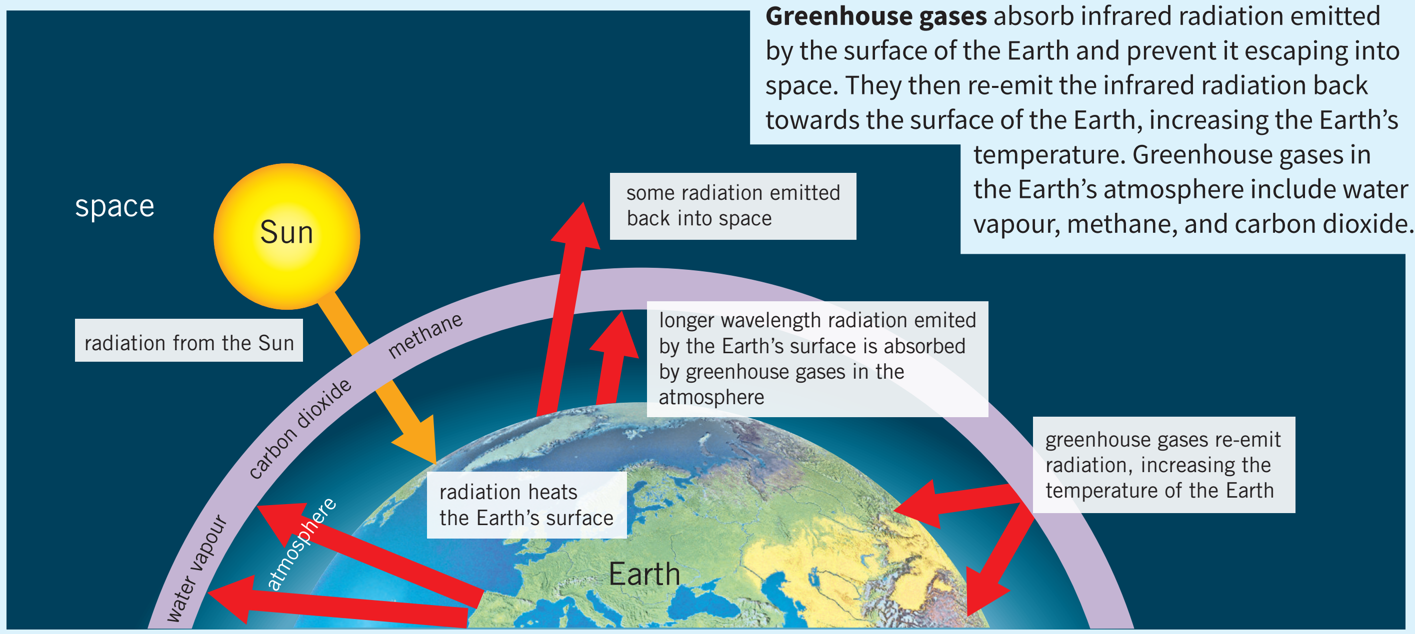
A **black body** is a theoretical object that absorbs 100% of the radiation that falls on it.

A perfect black body would not reflect or transmit any radiation, and would also be a perfect emitter of radiation.

Radiation and the Earth's temperature

The temperature of the Earth depends on lots of factors, including the rate at which visible light and infrared radiation are reflected, absorbed, and emitted by the Earth's atmosphere and surface.

Greenhouse gases absorb infrared radiation emitted by the surface of the Earth and prevent it escaping into space. They then re-emit the infrared radiation back towards the surface of the Earth, increasing the Earth's temperature. Greenhouse gases in the Earth's atmosphere include water vapour, methane, and carbon dioxide.



Human activities such as burning fossil fuels, deforestation, and livestock farming are increasing the amount of greenhouse gases in the Earth's atmosphere. This is causing the Earth's temperature to increase – a major cause of climate change.

Specific heat capacity

When a substance is heated or cooled the temperature change depends on:

- the substance's mass
- the type of material
- how much energy is transferred to it.

Every type of material has a **specific heat capacity** – the amount of energy needed to raise the temperature of 1 kg of the substance by 1 °C.

The energy transferred to the thermal store of a substance can be calculated from the substance's mass, specific heat capacity, and temperature change:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg°C) × temperature change (°C)

$$\Delta E = m\ c\ \Delta\theta$$

This equation will be given to you on the equation sheet, but you need to be able to select and apply it to the correct questions.

Key terms

Make sure you can write a definition for these key terms.

absorb | black body | electromagnetic spectrum | emit | greenhouse gas | infrared radiation | specific heat capacity | thermal conductivity | thermal insulator

Chapter 2: Energy transfer by heating

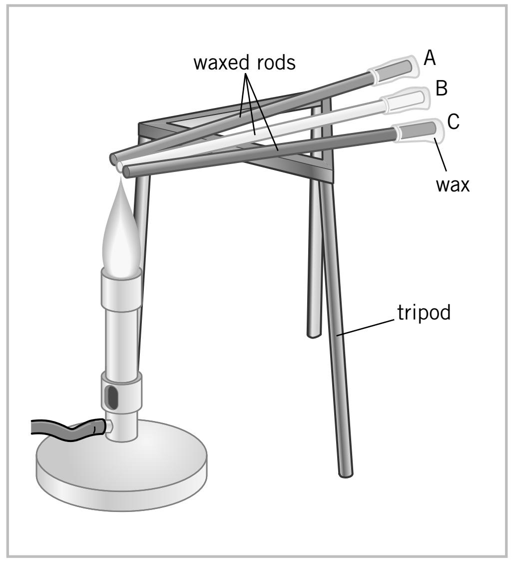
Knowledge organiser

Thermal conductivity

The **thermal conductivity** of a material tells you how ________________________________ ________________________________.

You can test the thermal conductivity of rods made of different metals using this experimental set-up. Each rod must have the same ________ and ________, and the same temperature difference between its ends.

One end of each rod is covered in ________ and the other ends are heated equally. The faster the wax melts, the ________________ ________________________.



Insulating buildings

Heating bills can be expensive so it is important to reduce the rate of ____________ loss from buildings.

Some factors that affect the rate of heat loss from a building include:

1.
2.

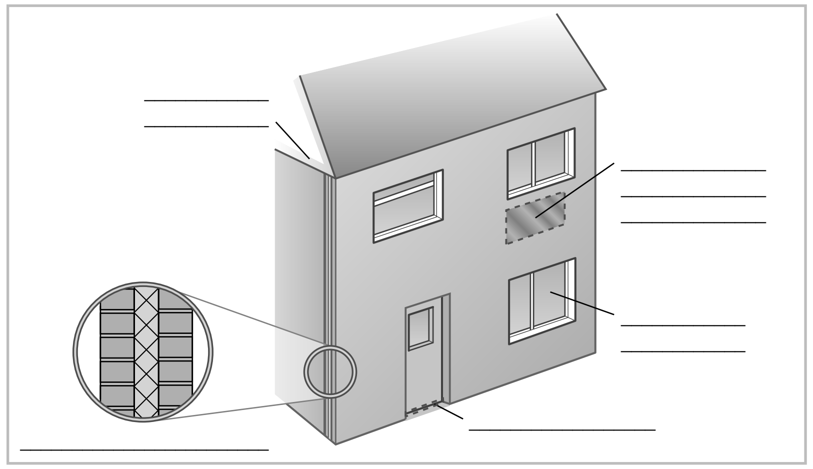
lower thermal conductivity =

The thermal conductivity of the walls and roof can be reduced by using ____________ ____________.

A thermal insulator is a material which has a ________ thermal conductivity. The rate of energy transfer through an insulator is _____.

The energy transfer per second through a material depends on:

1.
2.
3.



Infrared radiation

Infrared radiation is part of the ________________ ________________.

All objects ____________ and ____________ infrared radiation.

The higher the temperature of an object, the more infrared radiation it emits in a given time.

A good absorber of infrared radiation is also a good emitter.

For an object at a constant temperature:

- infrared radiation ____________ = infrared radiation absorbed
- infrared radiation is emitted across a continuous range of ____________.

An object's temperature will ____________ if it absorbs infrared radiation at a higher rate than it emits it. This rule applies to the planet Earth.

Black bodies

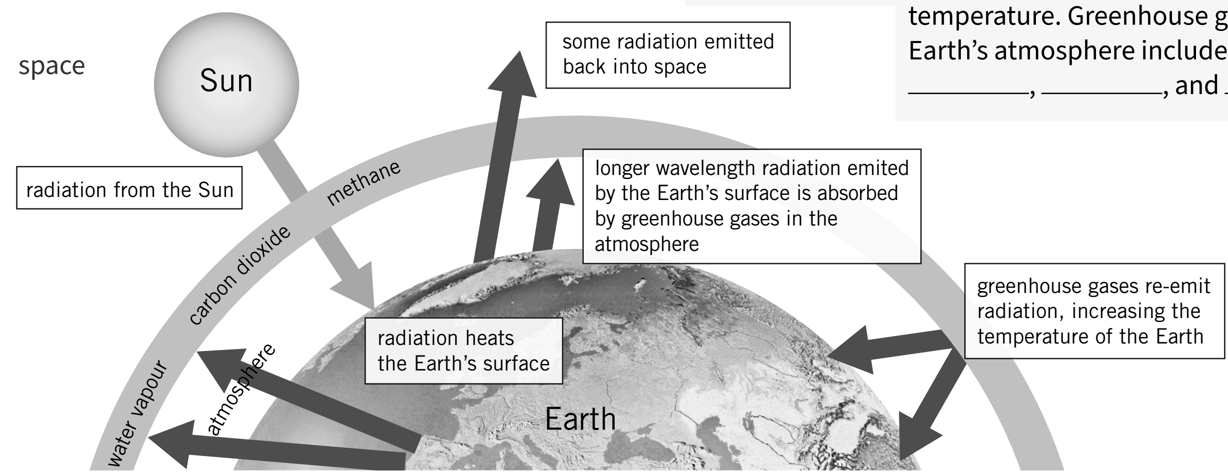
A **black body** is a theoretical object that absorbs _____ of the radiation that falls on it.

A perfect black body would not ________ or ________ any radiation, and would also be a perfect ________ of radiation.

Radiation and the Earth's temperature

The temperature of the Earth depends on lots of factors, including the rate at which visible light and infrared radiation are reflected, absorbed, and emitted by the Earth's ____________ and surface.

____________ ________ absorb infrared radiation emitted by the surface of the Earth and prevent it escaping into ________. They then re-emit the infrared radiation back towards the surface of the Earth, increasing the Earth's temperature. Greenhouse gases in the Earth's atmosphere include ________ ________, ________, and ________.



Human activities such as ____, and ________________ are increasing the amount of greenhouse gases in the Earth's atmosphere. This is causing the Earth's temperature to increase – a major cause of ____________ ____________.

Specific heat capacity

When a substance is heated or cooled the temperature change depends on:

-
-
-

Every type of material has a **specific heat capacity** – ____ ____

The energy transferred to the ____________ ________ of a substance can be calculated from the substance's mass, specific heat capacity, and temperature change:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg°C) × temperature change (°C)

$$\Delta E = m\,c\,\Delta\theta$$

This equation will be given to you on the equation sheet, but you need to be able to select and apply it to the correct questions.

Key terms

Make sure you can write a definition for these key terms.

absorb *black body* *electromagnetic spectrum* *emit* *greenhouse gas* *infrared radiation* *specific heat capacity* *thermal conductivity* *thermal insulator*

Chapter 2: Energy transfer by heating

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P2 questions	Answers
1	What does a material's thermal conductivity tell you?	
2	Which materials have low thermal conductivity?	
3	Give three factors that determine the rate of thermal energy transfer through a material.	
4	What factors affect the rate of heat loss from a building?	
5	Define specific heat capacity.	
6	What is infrared radiation?	
7	What is the relationship between the temperature of an object and its emission of infrared radiation?	
8	What can you tell about an object that absorbs and emits infrared radiation at the same rate?	
9	Compare the amount of infrared radiation emitted and absorbed by an object that is increasing in temperature.	
10	What is a black body?	
11	Name three greenhouse gases.	
12	What human activities increase the levels of greenhouse gases released?	
13	Why do greenhouse gases increase the Earth's temperature?	
14	To determine the specific heat capacity of a substance, what do you need to measure?	

Chapter 3: Energy resources

Knowledge organiser

Energy resources

The main ways in which we use the Earth's energy resources are:

- generating electricity
- heating
- transport.

Most of our energy currently comes from **fossil fuels** – coal, oil, and natural gas.

Reliability and environmental impact

Some energy resources are more reliable than others. **Reliable** energy resources are ones that are available all the time (or at predictable times) and in sufficient quantities.

Both **renewable** and **non-renewable** energy resources have some kind of **environmental impact** when we use them.

Non-renewable energy resources

- not replaced as quickly as they are used
- will eventually run out

For example, fossil fuels and nuclear fission.

Renewable energy resources

- can be replaced at the same rate as they are used
- will not run out

For example, solar, tidal, wave, wind, geothermal, biofuel, and hydroelectric energies.

Non-renewable energy resources

Resource	Main uses	Source	Advantages	Disadvantages
coal	generating electricity	extracted from underground	• enough available to meet current energy demands • reliable – supply can be controlled to meet demand • relatively cheap to extract and use	• will eventually run out • release carbon dioxide when burned – one of the main causes of climate change • release other polluting gases, such as sulfur dioxide (from coal and oil) which causes acid rain • oil spills in the oceans kill marine life
oil	generating electricity transport heating			
natural gas	generating electricity heating			
nuclear fission	generating electricity	mining naturally occurring elements, such as uranium and plutonium	• no polluting gases or greenhouse gases produced • enough available to meet current energy demands • large amount of energy transferred from a very small mass of fuel • reliable – supply can be controlled to meet demand	produces nuclear waste, which is: • dangerous • difficult and expensive to dispose of • stored for centuries before it is safe to dispose of. nuclear power plants are expensive to: • build and run • decommission (shut down).

Key terms

Make sure you can write a definition for these key terms.

biofuel · carbon neutral · environmental impact · fossil fuel · geothermal · hydroelectric · non-renewable · reliability · renewable

Renewable energy resources

Resource	Main uses	Source	Advantages	Disadvantages
solar energy	generating electricity heating	sunlight transfers energy to solar cells sunlight transfers energy to solar heating panels	can be used in remote places very cheap to run once installed no pollution/greenhouse gases produced	supply depends on weather expensive to buy and install cannot supply large scale demand
hydroelectric energy	generating electricity	water flowing downhill turns generators	low running cost no fuel costs reliable and supply can be controlled to meet demand	expensive to build hydroelectric dams flood a large area behind the dam, destroying habitats and resulting in greenhouse gas production from rotting vegetation
tidal energy	generating electricity	turbines on tidal barrages turned by water as the tide comes in and out	predictable supply as there are always tides can produce large amounts of electricity no fuel costs no pollution/greenhouse gases produced	tidal barrages: – change marine habitats and can harm animals – restrict access and can be dangerous for boats – are expensive to build and maintain cannot control supply supply varies depending on time of month
wave energy	generating electricity	floating generators powered by waves moving up and down	low running cost no fuel costs no pollution/greenhouse gases produced	floating generators: – change marine habitats and can harm animals – restrict access and can be dangerous for boats – are expensive to build, install, and maintain dependent on weather cannot supply large scale demand
wind energy	generating electricity	turbines turned by the wind	low running cost no fuel costs no pollution/greenhouse gases produced	supply depends on weather large amounts of land needed to generate enough electricity for large scale demand can produce noise pollution for nearby residents
geothermal energy	generating electricity heating	radioactive substances deep within the Earth transfer heat energy to the surface	low running cost no fuel costs no pollution/greenhouse gases produced	expensive to set up only possible in a few suitable locations around the world
biofuels	generating electricity transport	fuel produced from living or recently living organisms, for example, plants and animal waste	can be **carbon neutral** – the amount of carbon dioxide released when the fuel is burnt is equal to the amount of carbon dioxide absorbed when the fuel is grown reliable and supply can be controlled to meet demand	expensive to produce biofuels growing biofuels requires a lot of land and water that could be used for food production can lead to deforestation – forests are cleared for growing biofuel crops

Chapter 3: Energy resources

Knowledge organiser

Energy resources

The main ways in which we use the Earth's energy resources are:

-
-
-

Most of our energy currently comes from **fossil fuels** – ________, ________, and ________ ________.

Reliability and environmental impact

Some energy resources are more reliable than others. **Reliable** energy resources are ____ ____.

Both ___________ and ___________ energy resources have some kind of **environmental impact** when we use them. Name the issues below.

Non-renewable energy resources

-
-

For example, ___________ and ____________________.

Renewable energy resources

-
-

For example, ___________ ___________ ___________ and ____________________.

Non-renewable energy resources				
Resource	**Main uses**	**Source**	**Advantages**	**Disadvantages**
coal	•		• • •	• • • •
oil	• • •			
natural gas	• •			
nuclear fission	•		• • • •	produces nuclear waste, which is: • • • nuclear power plants are expensive to: • •

Renewable energy resources				
Resource	**Main uses**	**Source**	**Advantages**	**Disadvantages**
solar energy	• •		• • •	• • •
hydroelectric energy	•		• • •	• •
tidal energy	•		• • •	tidal barrages: • • • • •
wave energy	•		• • •	floating generators: • • • • •
wind energy	•		• • •	• • •
geothermal energy	• •		• • •	• •
biofuels	• •		• •	• • •

Key terms

Make sure you can write a definition for these key terms.

biofuel *carbon neutral* *environmental impact* *fossil fuel* *geothermal* *hydroelectric* *non-renewable* *reliability* *renewable*

Chapter 3: Energy resources

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P3 questions	Answers
1	What is a non-renewable energy resource?	
2	What is a renewable energy resource?	
3	What are the main renewable and non-renewable resources available on Earth?	
4	What are the main advantages of using coal as an energy resource?	
5	What are the main disadvantages of using coal as an energy resource?	
6	What are the main advantages of using nuclear fuel as an energy resource?	
7	What are the main disadvantages of using nuclear fuel as an energy resource?	
8	What are the main advantages of using solar energy?	
9	What are the main disadvantages of using solar energy?	
10	What are the main advantages of using tidal power?	
11	What are the main disadvantages of using tidal power?	
12	What are the main advantages of using wave turbines?	
13	What are the main disadvantages of using wave turbines?	
14	What are the main disadvantages of using wind turbines?	
15	What are the advantages and the disadvantages of using geothermal energy?	
16	What are the main advantages and disadvantages of using biofuels?	
17	What are the main advantages and disadvantages of using hydroelectric power?	

Chapter 4: Electric circuits

Knowledge organiser

Charge

An atom has no **charge** because it has equal numbers of positive protons and negative electrons.

When electrons are removed from an atom it becomes *positively* charged. When electrons are added to an atom it becomes *negatively* charged.

Static charge

Insulating materials can become charged when they are rubbed with another insulating material. This is because electrons are transferred from one material to the other. Materials that gain electrons become negatively charged and those that lose electrons become positively charged.

Positive charges do not usually transfer between materials.

Electric charge is measured in coulombs C.

Sparks

If two objects have a very strong electric field between them, electrons in the air molecules will be strongly attracted towards the positively charged object. If the electric field is strong enough, electrons will be pulled away from the air molecules and cause a flow of electrons between the two objects – this is a **spark**.

Drawing electric fields

A charged object creates an **electric field** around itself.

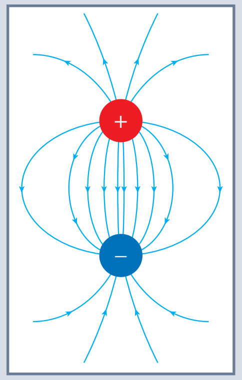
If a charged object is placed in the electric field of another charged object it experiences **electrostatic force**. This means that the two charged objects exert a non-contact force on each other:

- like charges repel each other
- opposing charges attract each other.

The electric field, and the force between two charged objects, gets stronger as the distance between the objects decreases.

Drawing electric fields

Electric fields can be represented using a diagram with field lines. These show the direction of the force that a small positive charge would experience when placed in the electric field.



When drawing electric fields, make sure:

- field lines meet the surface of charged objects at 90°
- arrows always point away from positive charges and towards negative charges.

Resistance

When electrons move through a circuit, they collide with the ions and atoms of the wires and components in the circuit. This causes **resistance** to the flow of charge.

The unit of resistance is the ohm (Ω).

A long wire has more resistance than a short wire because electrons collide with more ions as they pass through a longer wire.

The resistance of an electrical component can be found by measuring the current and potential difference:

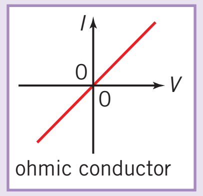
potential difference (V) = current (A) × resistance (Ω)

$V = IR$

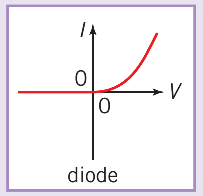
L

Current-potential difference graphs

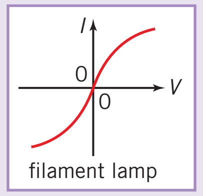
A graph of current through a component against the p.d. across it (I–V graph), is known as the component characteristic.



Current is directly proportional to the p.d. in an ohmic conductor at a constant temperature. The resistance is constant.



The current through a diode only flows in one direction – called the forward direction. There needs to be a minimum voltage before any current will flow.

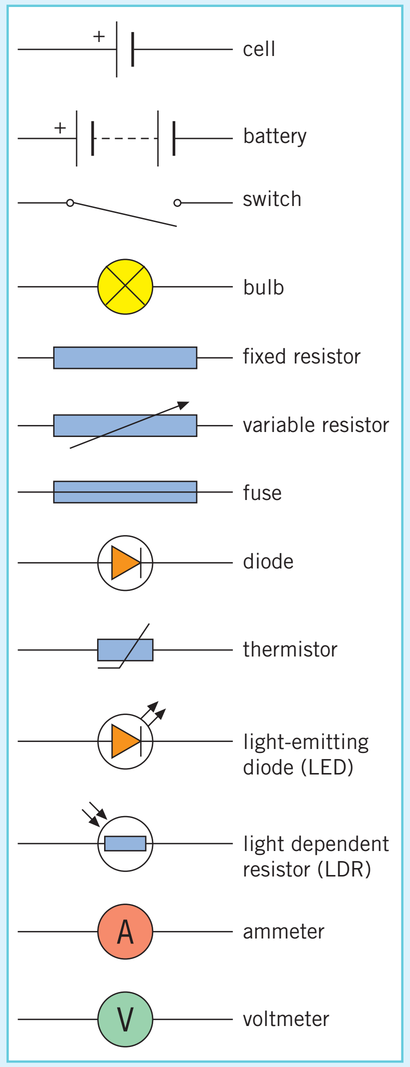


As more current flows through the filament, its temperature increases. The atoms in the wire vibrate more, and collide more often with electrons flowing through it, so resistance increases as temperature increases. The resistance of a thermistor decreases and temperature increases. The resistance of a light dependent resistor (LDR) decreases as light intensity increases.

The resistance of an ohmic conductor can be found by calculating the gradient at that point and taking the inverse:

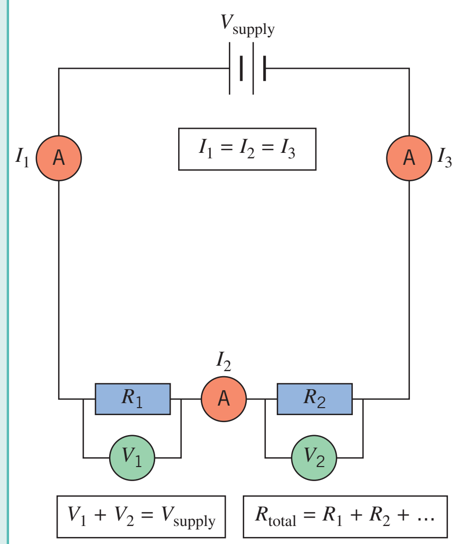
$$\text{resistance} = \frac{1}{\text{gradient}}.$$

Circuit components



Series circuits

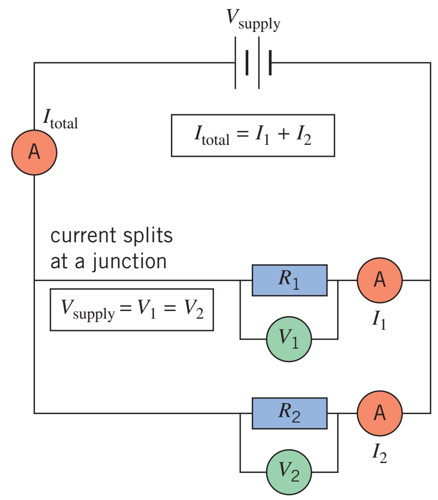
In a series circuit, the components are connected one after the other in a single loop. If one component in a series circuit stops working the whole circuit will stop working.



Components with a higher resistance will transfer a larger share of the total p.d. because $V = IR$ (and current is the same through all components).

Parallel circuits

A parallel circuit is made up of two or more loops through which current can flow. If one branch of a parallel circuit stops working, the other branches will not be affected.



The total resistance of two or more components in parallel is always less than the smallest resistance of any branch. This is because adding a loop to the circuit provides another route for the current to flow, so more current can flow in total even though the p.d. has not changed. Adding more resistors in parallel decreases the total resistance of a circuit.

Electric current

Electric current is when **charge** flows. The charge in an electric circuit is carried by electrons.

The unit of current is the ampere (amp, A).

1 ampere = 1 coulomb of charge flow per second

Charge (C) = current (A) x time (s)

In circuit diagrams, current flows from the positive terminal of a cell or battery to the negative terminal. This is known as conventional current.

In a single closed loop, the current has the same value at any point in the circuit.

Metals are good conductors of electricity because they contain delocalised electrons, which are free to flow through the structure.

Potential difference

Potential difference (p.d.) is a measure of how much energy is transferred between two points in a circuit. The unit of potential difference is the volt (V).

- The p.d. across a component is the work done on it by each coulomb of charge that passes through it.
- The p.d. across a power supply or battery is the energy transferred to each coulomb of charge that passes through it.

For electrical charge to flow through a circuit there must be a source of potential difference.

Potential difference (V) = energy transferred (J)/ charge (C)

Key terms

Make sure you can write a definition for these key terms.

ampere
charge
coulomb
current
electric field
electrostatic force
LDR
parallel
potential difference
resistance
series
static
thermistor

Chapter 4: Electric circuits

Knowledge organiser

Charge

An _____ has no **charge** because it has equal numbers of positive protons and negative electrons.

When electrons are removed from an atom it becomes _____ charged. When electrons are added to an atom it becomes _____ charged.

Static charge

Insulating materials can become charged when they are _____ with another insulating material. This is because electrons are _____ from one material to the other. Materials that _____ _____ become negatively charged and those that _____ _____ become positively charged.

_____ charges do not usually transfer between materials.

Electric charge is measured in _____.

Sparks

If two objects have a very _____ electric field between them, electrons in the _____ molecules will be strongly attracted towards the _____ _____ object. If the electric field is strong enough, electrons will be _____ away from the air molecules and cause a flow of electrons between the two objects – this is a **spark**.

Drawing electric fields

A _____ object creates an **electric field** around itself.

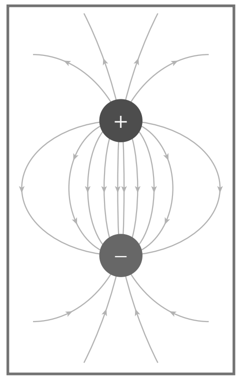
If a charged object is placed in the electric field of another charged object it experiences _____ _____. This means that the two charged objects exert a _____ force on each other:

- like charges _____ each other
- opposing charges _____ each other.

The electric field, and the force between two charged objects, gets _____ as the distance between the objects decreases.

Drawing electric fields

Electric fields can be represented using a diagram with _____ _____. These show the _____ of the force that a small positive charge would experience when placed in the electric field.



When drawing electric fields, make sure:

- field lines meet the surface of charged objects at _____
- arrows always point _____ from positive charges and _____ negative charges.

Resistance

When electrons move through a circuit, they _____ with the ions and atoms of the wires and components in the circuit. This causes _____ to the flow of charge.

The unit of resistance is the _____.

A _____ wire has more resistance than a _____ wire because electrons collide with more ions as they pass through a longer wire.

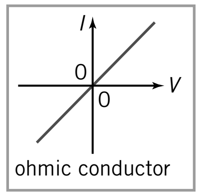
The resistance of an electrical component can be found by measuring the _____ and potential difference:

potential difference (V) = _____ (A) × _____ (Ω)

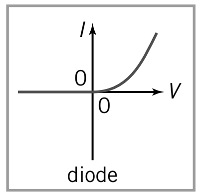
$V = IR$

Current–potential difference graphs

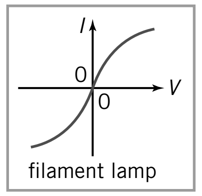
A graph of current through a component against the p.d. across it (I–V graph), is known as the _____ characteristic.



Current is _____ _____ to the p.d. in an ohmic conductor at a _____ temperature. The _____ is constant.



The current through a diode only flows in one direction – called the _____ _____. There needs to be a minimum _____ before any current will flow.



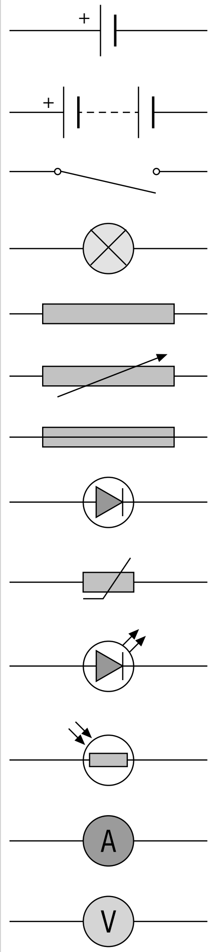
As more current flows through the filament, its temperature _____. The atoms in the wire _____ more, and collide more often with _____ flowing through it, so resistance increases as temperature _____. The resistance of a _____ decreases and temperature increases. The resistance of a light dependent resistor (LDR) _____ as light intensity increases.

The resistance of an ohmic conductor can be found by calculating the gradient at that point and taking the _____:

$\text{resistance} = \frac{1}{\text{gradient}}$.

Circuit components

Name the circuit components



_____
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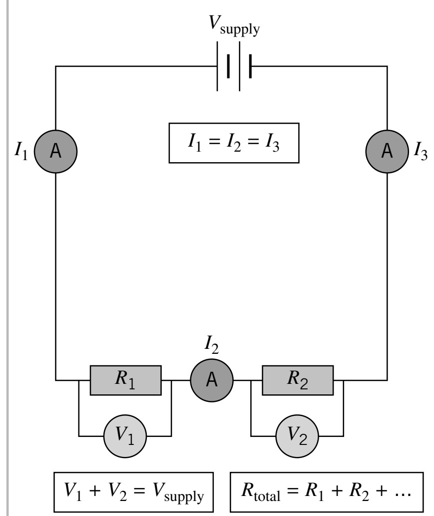
Series circuits

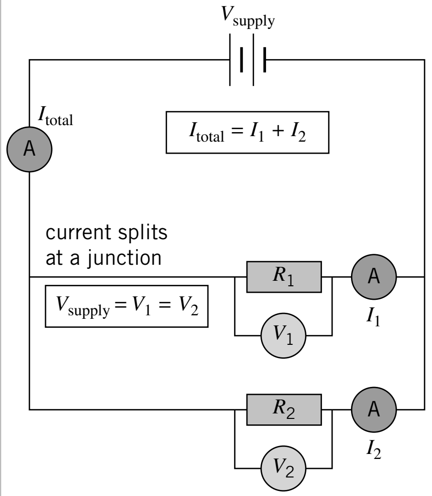
In a series circuit, the components are connected one after the other in a _____ loop. If one component in a series circuit stops working the _____ circuit will stop working.



Components with a higher _____ will transfer a larger share of the total p.d. because $V = IR$ (and current is the same through all components).

Parallel circuits

A parallel circuit is made up of two or more _____ through which current can flow. If one branch of a parallel circuit stops working, the other branches _____.



The total resistance of two or more components in parallel is always _____ than the smallest resistance of any branch. This is because adding a loop to the circuit provides another route for the current to flow, so more current can flow in total even though the p.d. has not changed. Adding more _____ in parallel decreases the total resistance of a circuit.

Electric current

Electric current is when _____ flows. The charge in an electric circuit is carried by electrons.

The unit of current is the _____.

1 ampere = 1 coulomb of charge flow per second

Charge (C) = current (A) x time (s)

In circuit diagrams, current flows from the _____ terminal of a cell or battery to the _____ terminal. This is known as _____.

In a single closed loop, the current has the same value at any point in the circuit.

Metals are good _____ of electricity because they contain _____ electrons, which are free to _____ through the structure.

Potential difference

Potential difference (p.d.) is _____ _____. The unit of potential difference is the _____.

- The p.d. across a component is the _____ on it by each coulomb of charge that passes through it.
- The p.d. across a power supply or battery is the _____ to each coulomb of charge that passes through it.

For electrical charge to flow through a circuit there must be a source of potential difference.

Potential difference (V) = energy transferred (J)/ charge (C)

Key terms

Make sure you can write a definition for these key terms.

ampere
charge
coulomb
current
electric field
electrostatic force
LDR
parallel
potential difference
resistance
series
static
thermistor

Chapter 4: Electric circuits

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P4 questions	Answers
1	How does a material become charged?	
2	What will two objects carrying the same type of charge do if they are brought close to each other?	
3	What is an electric field?	
4	What happens to the strength of an electric field as you get further from the charged object?	
5	What is electric current?	
6	What units are charge, current, and time measured in?	
7	What is the same at all points when charge flows in a closed loop?	
8	What must there be in a closed circuit so that electrical charge can flow?	
9	Which two factors does current depend on and what are their units?	
10	What happens to the current if the resistance is increased but the p.d. stays the same?	
11	What is an ohmic conductor?	
12	What happens to the resistance of a filament lamp as its temperature increases?	
13	What happens to the resistance of a thermistor as its temperature increases?	
14	What happens to the resistance of a light-dependent resistor when light intensity increases?	
15	What are the main features of a series circuit?	
16	What are the main features of a parallel circuit?	

Chapter 5: Electricity in the home

Knowledge organiser

Mains electricity

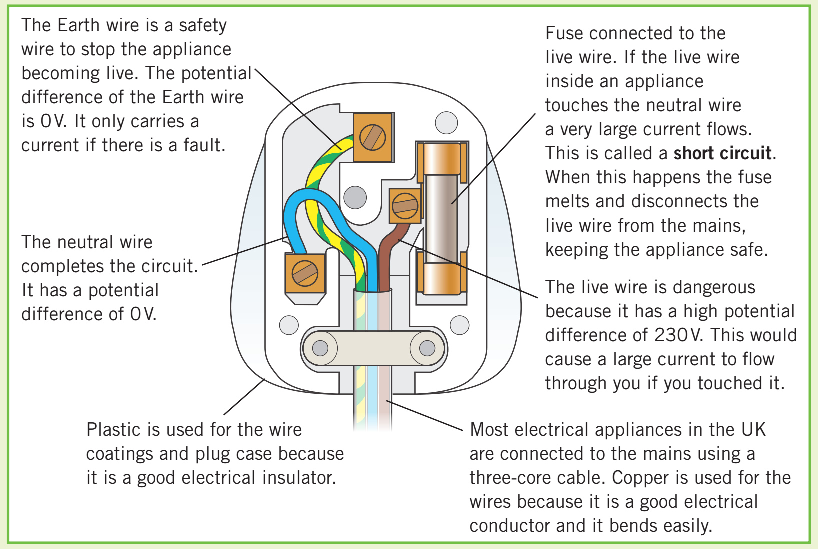
A cell or a battery provides a **direct current (dc)**. The current only flows in one direction and is produced by a **direct potential difference**.

Mains electricity provides an **alternating current (ac)**. The current repeatedly reverses direction and is produced by an **alternating potential difference**.

The positive and negative terminals of an alternating power supply swap over with a regular frequency.

The frequency of the mains electricity supply in the UK is 50 Hz and its voltage is 230 V.

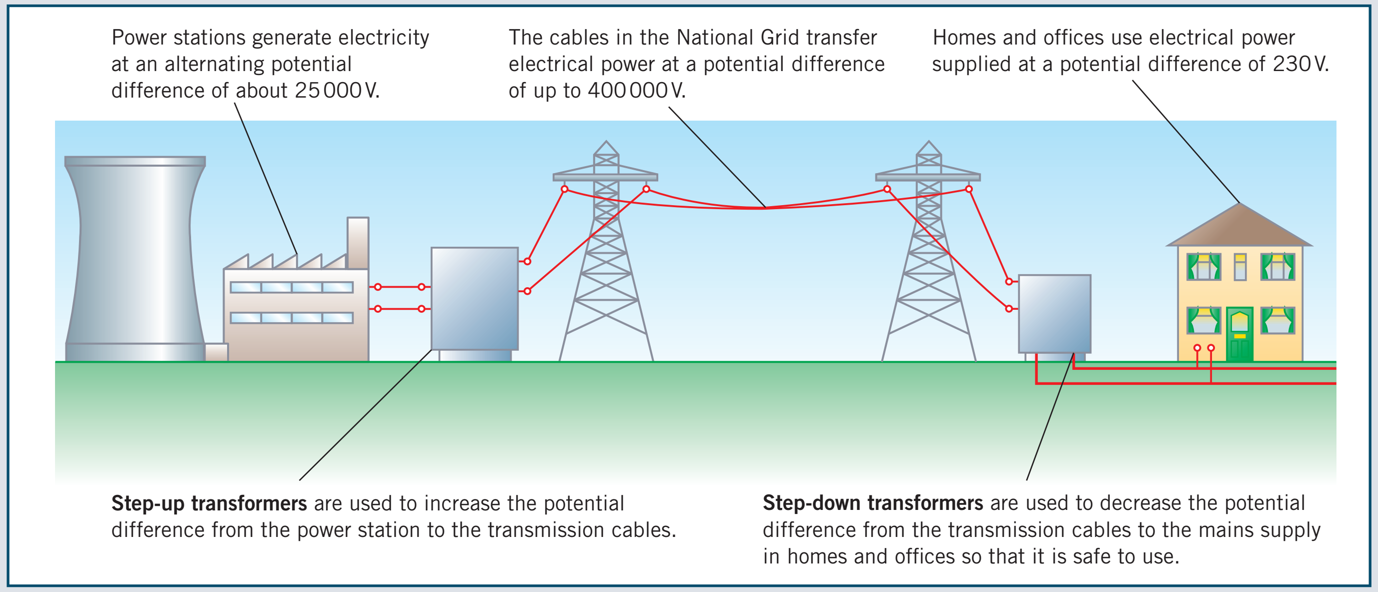
Plugs



The National Grid

The **National Grid** is a nationwide network of cables and transformers that link power stations to homes, offices, and other consumers of mains electricity.

Transformers are devices that can change the potential difference of an alternating current.



By making the grid potential difference much higher, a smaller current is needed to transfer the same power. Therefore, the National Grid is an efficient way to transfer power due to less heating loss in the wire.

Why do transformers improve efficiency?

A high potential difference across the transmission cables means that a lower current is needed to transfer the same amount of power, since:

power (W) = current (A) × potential difference (V)

$$P = IV$$ (L)

A lower current in the cables means less electrical power is wasted due to heating of the cables, since the power lost in heating a cable is:

power (W) = current^2 (A) × resistance (Ω)

$$P = I^2R$$ (L)

This makes the National Grid an efficient way to transfer energy.

If 100% efficiency is assumed:

primary potential difference × primary current = secondary potential difference × secondary current

$$V_p I_p = V_s I_s$$

Energy transfer in electrical appliances

Electrical appliances transfer energy.

For example, an hairdryer transfers energy electrically from a chemical store (e.g., the fuel in a power station) to the kinetic energy store of the fan inside the hairdryer and to the thermal energy store of the heating filaments inside the hairdryer.

When you turn an electrical appliance on, the potential difference of the mains supply causes charge (carried by electrons) to flow through it.

You can calculate the **charge flow** using the equation:

(L) charge flow (C) = current (A) × time (s)

$$Q = It$$

You can find the energy transferred to an electrical appliance when charge flows through it using:

(L) energy transferred (J) = charge flow (C) × potential difference (V)

$$E = QV$$

You can find the energy transferred by an electrical appliance using the equation:

(L) energy transferred (J) = power (W) x time (s)

Key terms

Make sure you can write a definition for these key terms.

alternating current · alternating potential difference · charge flow · coulombs · direct current · direct potential difference · fuse · National Grid · short circuit · step-down transformer · step-up transformer

Chapter 5: Electricity in the home

Knowledge organiser

Mains electricity

A cell or a battery provides a ______ ______. The current only flows in ______ direction and is produced by a ______ **potential difference**.

Mains electricity provides an ______ ______. The current repeatedly ______ direction and is produced by an ______ **potential difference**.

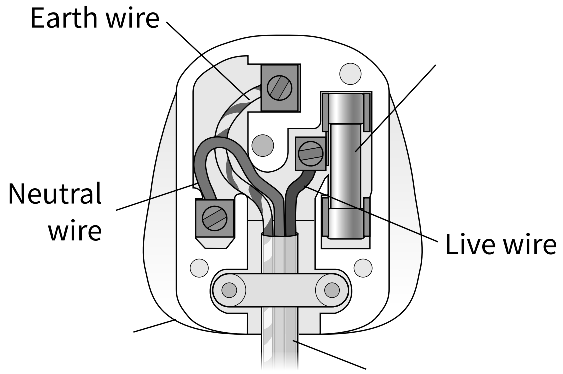
The ______ and ______ terminals of an alternating power supply swap over with a regular ______.

The frequency of the mains electricity supply in the UK is ______ and its voltage is ______.

Plugs

Label the diagram and name the colours of the wires in the table.

Wire	Colour
Live	
Neutral	
Earth	



Why do transformers improve efficiency?

A high potential difference across the transmission cables means that a ______ current is needed to transfer the same amount of power, since:

power (W) = ______ (A) × ______ (V)

P = ______ (L)

A lower current in the cables means less electrical power is ______ due to heating of the cables, since the power lost in heating a cable is:

power (W) = ______ ^{2} (A) × ______ (Ω)

P = ______ (L)

This makes the National Grid an ______ way to transfer energy.

If 100% ______ is assumed:

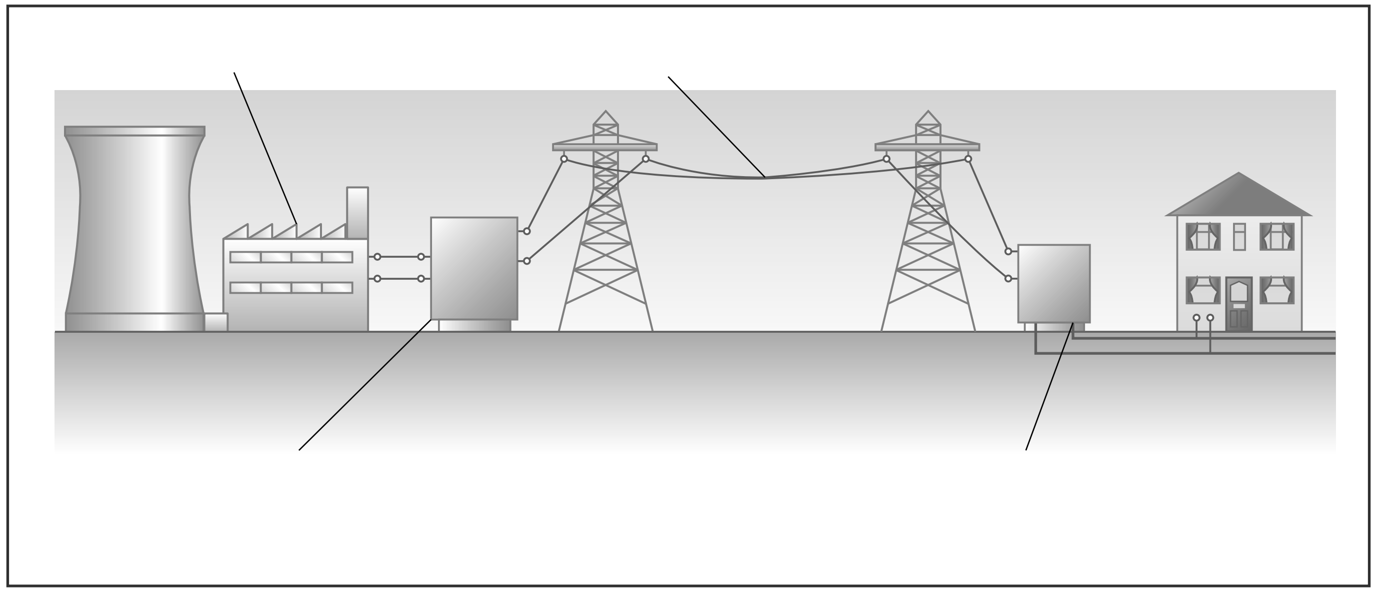
______ potential difference × primary current = ______ potential difference × secondary current

$V_p I_p = V_s I_s$

The National Grid

The **National Grid** is a nationwide ______ of cables and transformers that link ______ ______ to homes, offices, and other consumers of mains electricity.

Transformers are devices that can change the ______ ______ of an alternating current.



By making the grid potential difference much ______, a smaller current is needed to transfer the same power. Therefore, the National Grid is an efficient way to transfer power due to less ______ loss in the wire.

Energy transfer in electrical appliances

Electrical appliances ______ energy.

For example, a hairdryer transfers energy electrically from a ______ ______ (e.g., the fuel in a power station) to the ______ ______ ______ of the fan inside the hairdryer and to the ______ ______ ______ of the heating filaments inside the hairdryer.

When you turn an electrical appliance on, the potential difference of the ______ supply causes charge (carried by ______) to flow through it.

You can calculate the **charge flow** using the equation:

(L) charge flow (C) = ______ (A) × ______ (s)

Q = ______

You can find the energy transferred to an electrical appliance when charge flows through it using:

(L) energy transferred (J) = ______ (C) × ______ (V)

E = ______

You can find the energy transferred by an electrical appliance using the equation:

(L) energy transferred (J) = ______ (W) × ______ (s)

Key terms

Make sure you can write a definition for these key terms.

alternating current, alternating potential difference, charge flow, coulombs, direct current, direct potential difference, fuse, National Grid, short circuit, step-down transformer, step-up transformer

Chapter 5: Electricity in the home

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P5 questions	Answers
1	Why is the current provided by a cell called a direct current (d.c.)?	
2	What is an alternating current (a.c.)?	
3	What kind of current is supplied by mains electricity?	
4	What is the frequency and voltage of mains electricity?	
5	What colours are the live, neutral, and earth wires in a three-core cable?	
6	What is the function of the live wire in a three-core cable?	
7	What is the function of the neutral wire in a three-core cable?	
8	What is the function of the earth wire in a three-core cable?	
9	When is there a current in the earth wire?	
10	Why is the live wire dangerous?	
11	What is the National Grid?	
12	What are step-up transformers used for in the National Grid?	
13	What are step-down transformers used for in the National Grid?	
14	How does having a large potential difference in the transmission cables help to make the National Grid an efficient way to transfer energy?	
15	What two things does energy transfer to an appliance depend on?	
16	What are the units for power, current, potential difference, and resistance?	

Chapter 6: Molecules and matter

Knowledge organiser

Changes of state

Changes of state and conservation of mass

Changes of state are physical changes because no new substances are produced. The mass always stays the same because the number of particles does not change.

Particles and kinetic energy

When the temperature of a substance is increased, the kinetic energy store of its particles increases and the particles vibrate or move faster.

If the kinetic store of a substance's particles increases or decreases enough, the substance may change state.

Density

You can calculate the density of an object if you know its mass and volume:

$$\text{density (kg/m}^3\text{)} = \frac{\text{mass (kg)}}{\text{volume (m}^3\text{)}}$$

$$\rho = \frac{m}{V}$$

States of matter

Gas

Arrangement	• particles are spread out • almost no forces of attraction between particles • large distance between particles on average
Movement	• particles move randomly at high speed
Properties	• low density • no fixed volume or shape • can be compressed and can flow • spread out to fill all available space

Liquid

Arrangement	• particles are in contact with each other • forces of attraction between particles are weaker than in solids
Movement	• particles are free to move randomly around each other
Properties	• usually lower density than solids • fixed volume • shape is not fixed so they can flow

Solid

Arrangement	• particles held next to each other in fixed positions by strong forces of attraction
Movement	• particles vibrate about fixed positions
Properties	• high density • fixed volume • fixed shape (unless deformed by an external force)

Internal energy

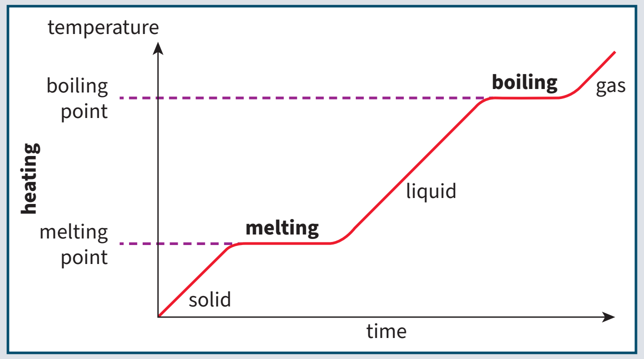
Heating a substance increases its **internal energy**.

Internal energy is the sum of the total kinetic energy the particles have due to their motion and the total potential energy the particles have due to their positions relative to each other.

Latent heat

In a graph showing the change in temperature of a substance being heated or cooled, the flat horizontal sections show when the substance is changing state.

The energy transfers taking place during a change in state do not cause a change in temperature, but do change the internal energy of the substance.



The energy transferred when a substance changes state is called the **latent heat**.

Specific latent heat – the energy required to change 1 kg of a substance with no change in temperature.

Specific latent heat of fusion – the energy required to melt 1 kg of a substance with no change in temperature.

Specific latent heat of vaporisation – the energy required to evaporate 1 kg of a substance with no change in temperature.

The energy needed to change the state of a substance can be calculated using the equation:

$$\text{thermal energy for a change in state (J)} = \text{mass (kg)} \times \text{specific latent heat (J/kg)}$$

$$E = m \times l$$

The relationship between temperature and pressure in gases

Gas temperature

The particles in a gas are constantly moving in random directions and with random speeds.

The temperature of a gas is related to the average kinetic energy of its particles.

When a gas is heated, the particles gain kinetic energy and move faster, so the temperature of the gas increases.

Gas pressure

The pressure a gas exerts on a surface, such as the walls of a container, is caused by the force of the gas particles hitting the surface.

The pressure of a gas produces a net force at right angles to the walls of a container or any surface.

If the temperature of a gas in a sealed container is increased, the pressure increases because

- the particles move faster so they hit the surfaces with more force
- the number of these impacts per second increases, exerting more force overall.

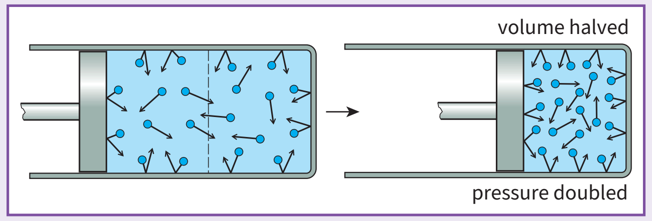
If a gas is compressed quickly, for example, in a bicycle pump, its temperature can rise. This is because

- compressing the gas requires a force to be applied to the gas – this results in work being done to the gas, since work done = force × distance
- the energy gained by the gas is not transferred quickly enough to its surroundings.

The relationship between volume and pressure in gases

If the volume of a fixed mass of gas at a constant temperature is decreased, the pressure increases because

- the distance the particles travel between each impact with a container wall is smaller
- the number of impacts per second increases, so the total force of impacts increases.



Similarly, if the volume is increased, the pressure decreases. This is because

- the distance the particles travel between each impact with a wall of the container is greater
- the number of impacts per second decreases, so the total force of the impacts decreases.

The pressure and volume of a fixed mass of gas at a constant temperature are linked by the equation:

$$\text{pressure (Pa)} \times \text{volume (m}^3\text{)} = \text{constant}$$

$$p \times V = \text{constant}$$

Rearranging this equation gives:

$$p = \frac{\text{constant}}{V} \quad \text{and} \quad V = \frac{\text{constant}}{p}$$

This shows that pressure is inversely proportional the volume of a gas.

Key terms

Write a definition for these key terms.

boiling, condensation, conservation of mass, density, evaporation, freezing, fusion, internal energy, latent heat, melting, specific latent heat, sublimation, vaporisation

Chapter 6: Molecules and matter

Knowledge organiser

Changes of state

Changes of state and conservation of mass

Changes of state are __________ changes because no new substances are produced. The mass always stays the __________ because the number of particles does not change.

Particles and kinetic energy

When the temperature of a substance is __________, the __________ energy store of its particles increases and the particles vibrate or move __________.

If the kinetic store of a substance's particles increases or decreases enough, the substance may change __________.

Density

You can calculate the density of an object if you know its mass and volume:

$$\text{density (kg/m}^3\text{)} = \frac{\text{\_\_\_\_\_\_\_\_\_\_ (kg)}}{\text{\_\_\_\_\_\_\_\_\_\_ (m}^3\text{)}}$$

$$\rho = \frac{m}{V}$$

L

Internal energy

__________ a substance increases its **internal energy**.

Internal energy is the __________ of the total kinetic energy the particles have due to their __________ and the total potential energy the particles have due to their positions relative to each other.

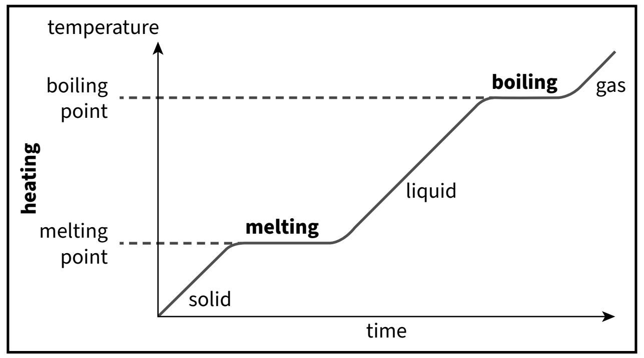
States of matter

Gas	**Arrangement**	• • •
	Movement	•
	Properties	• • • •
Liquid	**Arrangement**	• •
	Movement	•
	Properties	• • •
Solid	**Arrangement**	•
	Movement	•
	Properties	• • •

Latent heat

In a graph showing the change in __________ of a substance being heated or cooled, the flat horizontal sections show when the substance is changing state.

The energy transfers taking place during a change in state do not cause a change in temperature, but do change the __________ energy of the substance.



The energy transferred when a substance changes state is called the __________ __________. Define the following terms.

Specific latent heat – __________

Specific latent heat of fusion – __________

Specific latent heat of vaporisation – __________

The energy needed to change the state of a substance can be calculated using the equation:

$$\text{thermal energy for a change in state (J)} = \text{\_\_\_\_\_\_ (kg)} \times \text{\_\_\_\_\_\_ \_\_\_\_\_\_ (J/kg)}$$

$$E = m \times l$$

The relationship between temperature and pressure in gases

Gas temperature

The particles in a gas are constantly moving in __________ directions and with random __________.

The temperature of a gas is related to the average __________ energy of its particles.

When a gas is heated, the particles gain kinetic energy and move __________, so the temperature of the gas increases.

Gas pressure

The pressure a gas exerts on a __________, such as the walls of a container, is caused by the force of the gas particles hitting the surface.

The pressure of a gas produces a __________ force at right angles to the walls of a container or any surface.

If the temperature of a gas in a sealed container is increased, the pressure increases because

- the particles move __________ so they hit the surfaces with more force
- the number of these impacts per second increases, exerting more __________ overall.

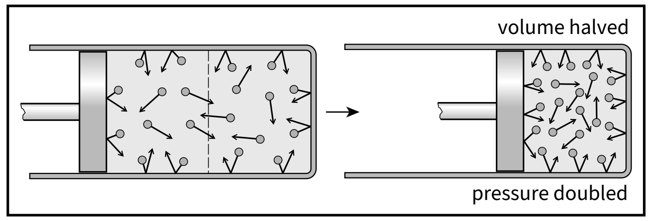
If a gas is compressed quickly, for example, in a bicycle pump, its temperature can __________. This is because

- compressing the gas requires a __________ to be applied to the gas – this results in work being done to the gas, since work done = force × distance
- the energy __________ by the gas is not transferred quickly enough to its surroundings.

The relationship between volume and pressure in gases

If the volume of a fixed mass of gas at a constant temperature is decreased, the pressure __________ because

- the distance the particles travel between each impact with a container wall is __________
- the number of impacts per second increases, so the total force of impacts increases.



Similarly, if the volume is increased, the pressure decreases. This is because

- the distance the particles travel between each impact with a wall of the container is __________
- the number of impacts per second __________, so the total force of the impacts decreases.

The pressure and volume of a fixed mass of gas at a constant temperature are linked by the equation:

__________ (Pa) × __________ (m^3) = __________

$$p \times V = \text{constant}$$

Rearranging this equation gives:

$$p = \frac{\text{constant}}{V} \quad \text{and} \quad V = \frac{\text{constant}}{p}$$

This shows that pressure is __________ __________ the volume of a gas.

Key terms

Write a definition for these key terms.

boiling, condensation, conservation of mass, density, evaporation, freezing, fusion, internal energy, latent heat, melting, specific latent heat, sublimation, vaporisation

Chapter 6: Molecules and matter

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P6 questions	Answers
1	Which two quantities do you need to measure to find the density of a solid or liquid?	
2	What happens to the particles in a substance if its temperature is increased?	
3	Why are changes of state physical changes?	
4	Why is the mass of a substance conserved when it changes state?	
5	What is the internal energy of a substance?	
6	Why does a graph showing the change in temperature as a substance cools have a flat section when the substance is changing state?	
7	What is the name given to the energy transferred when a substance changes state?	
8	What is the specific latent heat of a substance?	
9	What is the specific latent heat of fusion a substance?	
10	What is the specific latent heat of vaporisation of a substance?	
11	On a graph of temperature against time for a substance being heated up or cooled down, what do the flat (horizontal) sections show?	
12	What property of a gas is related to the average kinetic energy of its particles?	
13	What causes the pressure of a gas on a surface?	
14	Give two reasons why the pressure of a gas in a sealed container increases if its temperature is increased.	
15	Give two reasons why the temperature of a gas increases if it is compressed quickly.	
16	Explain why the pressure of a fixed mass of gas decreases if the volume is increased and kept at constant temperature.	

Chapter 7: Radioactivity 1

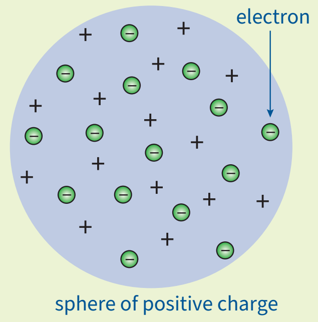
Knowledge organiser

Dalton's model

John Dalton thought the atom was a neutral solid sphere you cannot divide into smaller parts.

Plum pudding model

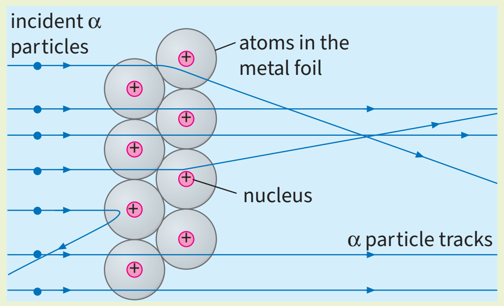
The discovery of negatively charged electrons led to the plum pudding model – a cloud of positive charge with electrons embedded in it.



Alpha scattering experiment

Positively charged alpha particles were fired at a thin sheet of gold foil.

- Most went straight through
- Some were deflected by small amounts
- 1 in 10 0000 deflected through large angles



Nuclear model

To explain the results, scientists deduced that there is a small positively charged nucleus at the centre of the atom where most of the mass is concentrated. The negative electrons orbit the nucleus.

Bohr's model

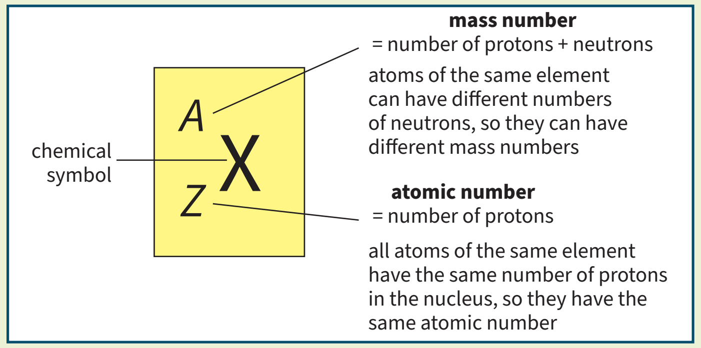
Bohr suggested the electrons orbit at specific distances called energy levels.

Basic structure of an atom

The nucleus, which is 10 000 times smaller than the radius of the atom, consists of two particles:

- positively charged protons
- neutrons which are neutral

An atom is uncharged overall and has equal numbers of protons and electrons.



Isotopes are atoms of the same element, with the same number of protons but a different numbers of neutrons.

Radioactive decay

Radioactive decay is when nuclear radiation is emitted by unstable atomic nuclei so that they become more stable. It is a *random* process. This radiation can knock electrons out of atoms in a process called **ionisation**.

Type of radiation	Change in the nucleus	Ionising power	Range in air	Stopped by	Decay equation
α alpha particle (two protons and two neutrons)	nucleus loses two protons and two neutrons	highest ionising power	travels a few centimetres in air	stopped by a sheet of paper	${}^{A}_{Z}X \rightarrow {}^{(A-4)}_{(Z-2)}Y + {}^{4}_{2}\alpha$
β beta particle (fast-moving electron)	a neutron changes into a proton and an electron	high ionising power	travels ≈ 1 m in air	stopped by a few millimetres of aluminium	${}^{A}_{Z}X \rightarrow {}_{(Z+1)}^{A}Y + {}^{0}_{-1}\beta$
γ gamma radiation (short-wavelength, high-frequency EM radiation)	some energy is transferred away from the nucleus	low ionising power	virtually unlimited range in air	stopped by several centimetres of thick lead or metres of concrete	${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$

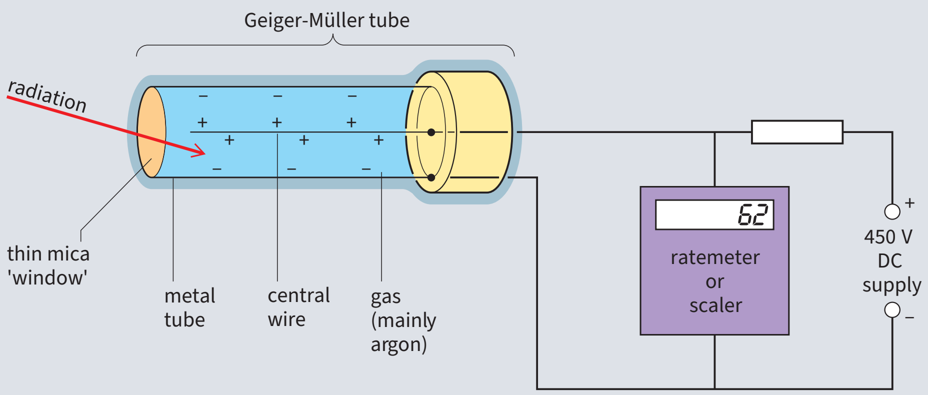
Activity and count rate

The **activity** of a radioactive source is the rate of decay of an unstable nucleus, measured in becquerel (Bq).

1 Bq = 1 decay per second

Detectors (e.g., **Geiger-Müller tubes**) record a **count rate** (number of decays detected per second).

$$\text{count rate after } n \text{ half-lives} = \frac{\text{initial count rate}}{2^n}$$



Half-life

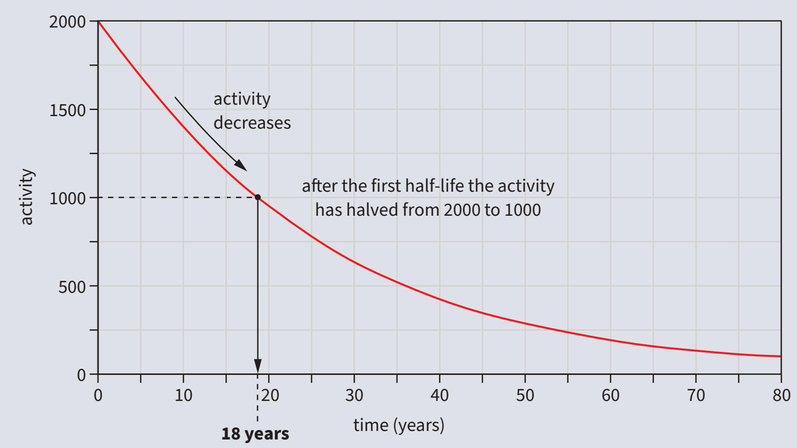
The **half-life** of a radioactive source is the time

- for half the number of unstable nuclei in a sample to decay
- for the count rate or activity of a source to halve.

The half-life of a source can be found from a graph of its count rate or activity against time.

To find the reduction in activity after a given number of half-lives:

1. calculate the activity after each half-life
2. subtract the final activity from the original activity.



The time taken for the activity to halve is 18 years. This is the half-life of this substance.

(HT only) Net decline can be given as a ratio: $\text{net daecline} = \frac{\text{reduction in activity}}{\text{original activity}}$

Chapter 7: Radioactivity 2

Knowledge organiser

Ionising radiation

Living cells can be damaged or killed by ionising radiation.

The risk depends on the half-life of the source and the type of radiation.

Alpha radiation is very dangerous inside the body because it affects all the surrounding tissue. Outside the body it only affects the skin and eyes because it cannot penetrate further.

Beta and gamma radiation are dangerous outside and inside the body because they can penetrate into tissues.

Radiation dose

Radiation dose, measured in sievert (Sv), measures the health risk of exposure to radiation. It depends on the type and amount of radiation.

Background radiation

Background radiation is radiation that is around us all the time. It comes from:

- natural sources like rocks and cosmic rays
- nuclear weapons and nuclear accidents.

Background radiation is always present but the levels are higher in some locations and in some jobs.

Nuclear waste

When fuel rods are removed from the reactor, they are stored in large tanks in water for up to a year until they cool down.

Machines are then used to open up fuel rods and extract the unused plutonium and uranium. Any material that is left then has to be stored securely as they have lots of radioactive isotopes with long half-lives. This is done to prevent radioactive contamination.

Irradiation versus contamination

irradiation	when an object is exposed to nuclear radiation	cause harm through ionisation	prevented by shielding, removing, or moving away from the source of radiation
contamination	when atoms of a radioactive material are on or in an object		object remains exposed to radiation as long as it is contaminated contamination can be very difficult to remove

Nuclear radiation in medicine

Exploration of internal organs

Gamma-emitting **tracers** are injected or swallowed by a patient. Gamma cameras can then create an image showing where the tracer has gone.

The half-life of the tracer must be short enough so that most of the nuclei will decay shortly after the image is taken to limit the patient's radiation dose (normally about six hours).

Control or destruction of unwanted tissue

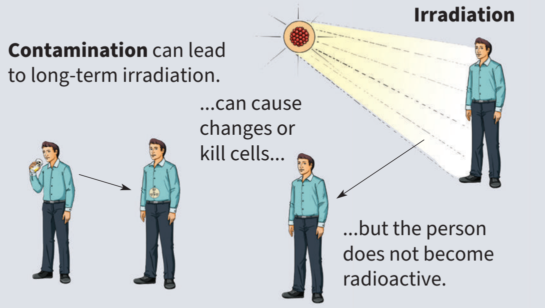
1. Narrow beams of gamma radiation can be focused on tumour cells to destroy them. Gamma is used because it can penetrate tumours from outside the body.
2. Beta- or gamma-emitting implants can be surgically placed inside (or next to) tumours. Their half-lives must be long enough to be effective, but short enough that it does not continue to irradiate the patient after treatment.

Protection against irradiation and contamination

You can protect against irradiation and contamination by:

- maintaining a distance from the radiation source
- limiting time near the source
- shielding from the radiation.

Studies on the effects of radiation should be published, shared with other scientists, and checked by **peer review** as they are important for human health.



Nuclear fission

Nuclear fission is when a large unstable nucleus absorbs an extra neutron and splits into two smaller nuclei of roughly equal size.

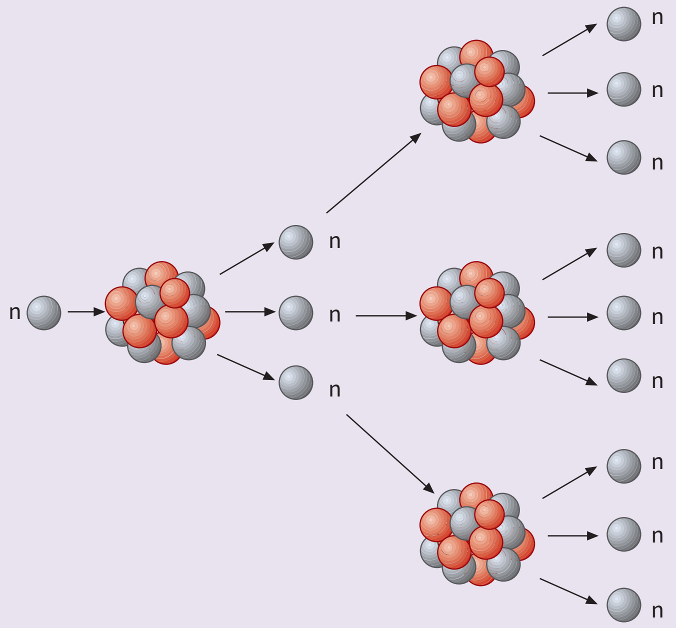
During nuclear fission:

- gamma radiation is emitted and energy is released
- two or three neutrons are emitted that can go on to cause a **chain reaction**.

The chain reaction in a power station reactor is controlled by absorbing neutrons.

Nuclear explosions are uncontrolled chain reactions.

On rare occasions an unstable nucleus splits apart without absorbing a neutron. This is called **spontaneous fission**.



Nuclear fusion

Nuclear fusion is when two light nuclei join to make a heavier one.

Some of the mass is converted to energy and transferred as radiation.

Nuclear fusion in the sun's core releases energy. A fusion reactor has to be at a very high temperature so the nuclei can overcome their repulsion.

Nuclear fusion in the future

Future fusion reactors could meet energy needs for a growing population. This is because:

- The fuel for fusion reactors is easily available as heavy hydrogen is naturally present in sea water.
- The product, helium, is an unreactive gas and non-radioactive so is harmless.
- The energy released could be used to generate electricity in the future.

Key terms

Make sure you can write a definition for these key terms.

atom alpha activity atomic number background radiation beta chain reaction contamination count rate electron fission fusion gamma Geiger-Müller tube half-life ionisation irradiation isotope mass number net decline neutron plum pudding model proton peer review radiation dose radioactive decay spontaneous tracer

Chapter 7: Radioactivity 1

Knowledge organiser

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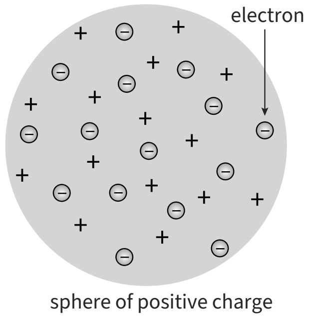

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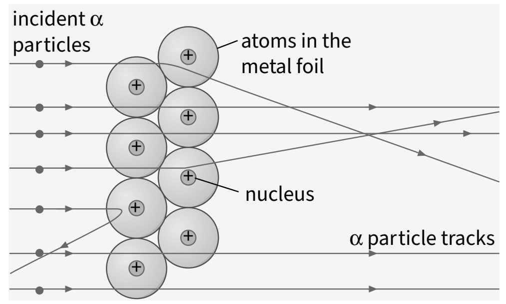

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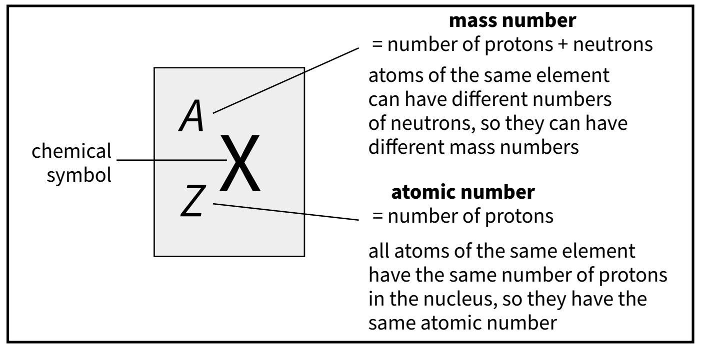

Isotopes are ______________________________
______________________________.

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Radioactive decay is when nuclear radiation is emitted by ______ atomic nuclei so that they become more stable. It is a *random* process. This radiation can knock electrons out of atoms in a process called ______.

Type of radiation	Change in the nucleus	Ionising power	Range in air	Stopped by	Decay equation
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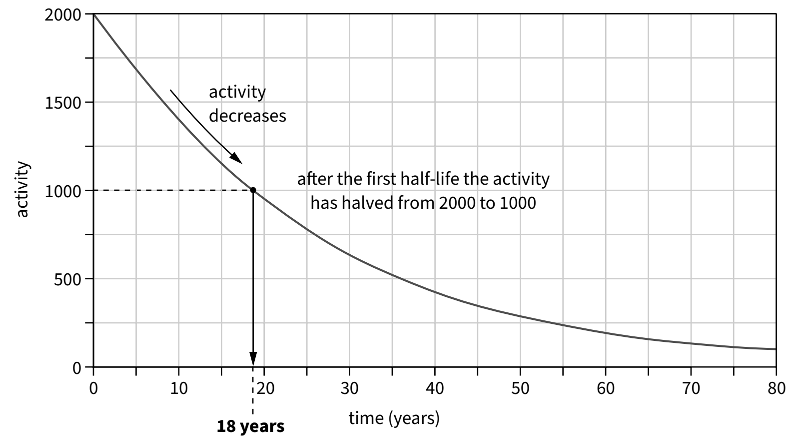

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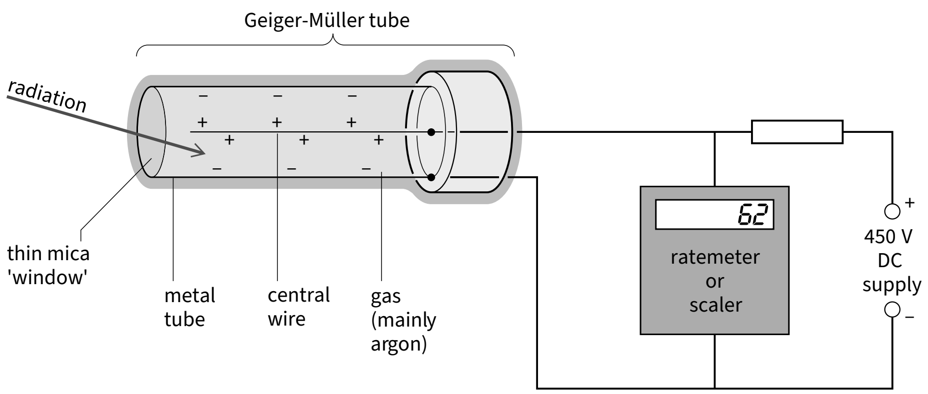

Chapter 7: Radioactivity 2

Knowledge organiser

Ionising radiation

____ cells can be damaged or killed by ionising radiation.

The risk depends on the ____ of the source and the type of radiation.

Alpha radiation is very dangerous inside the body because it affects all the ____ tissue. Outside the body it only affects the ____ and ____ because it cannot penetrate further.

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Radiation dose

Radiation dose, measured in ____ (Sv), measures the health risk of exposure to radiation. It depends on the type and amount of radiation.

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-
-

Background radiation is always present but the levels are higher in some locations and in some jobs.

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Machines are then used to open up fuel rods and extract the unused ____ and ____. Any material that is left then has to be stored securely as they have lots of radioactive ____ with long half-lives. This is done to prevent radioactive ____.

Irradiation versus contamination

irradiation	when an object is ____ to nuclear radiation	cause harm through ____	prevented by ____, ____, or ____ away from the source of radiation
contamination	when atoms of a radioactive material are on or in an ____		object remains ____ to radiation as long as it is contaminated contamination can be very difficult to remove

Nuclear radiation in medicine

Exploration of internal organs

Gamma-emitting ____ are injected or swallowed by a patient. Gamma cameras can then create an image showing where the tracer has gone.

The half-life of the tracer must be short enough so that most of the nuclei will ____ shortly after the image is taken to limit the patient's radiation dose (normally about ____ hours).

Control or destruction of unwanted tissue

1. Narrow beams of gamma radiation can be focused on ____ cells to destroy them. Gamma is used because it can penetrate tumours from outside the body.
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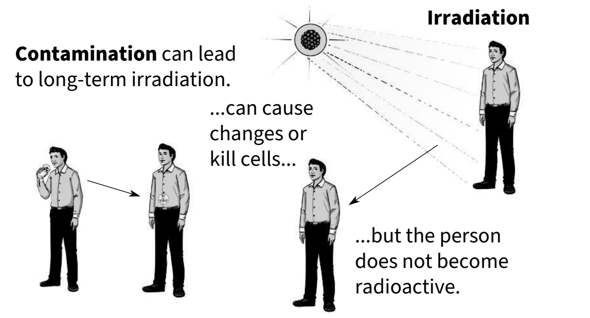
You can protect against irradiation and contamination by:

-
-
-

Studies on the effects of radiation should be published, shared with other scientists, and checked by ____ ____ as they are important for human health.



Nuclear fission

Nuclear fission is when a large unstable ____ absorbs an extra ____ and splits into ____ smaller nuclei of roughly equal size.

During nuclear fission:

- gamma radiation is emitted and ____ is released
- two or three neutrons are emitted that can go on to cause a ____ ____.

The chain reaction in a power station reactor is controlled by ____ neutrons.

Nuclear explosions are uncontrolled chain reactions.

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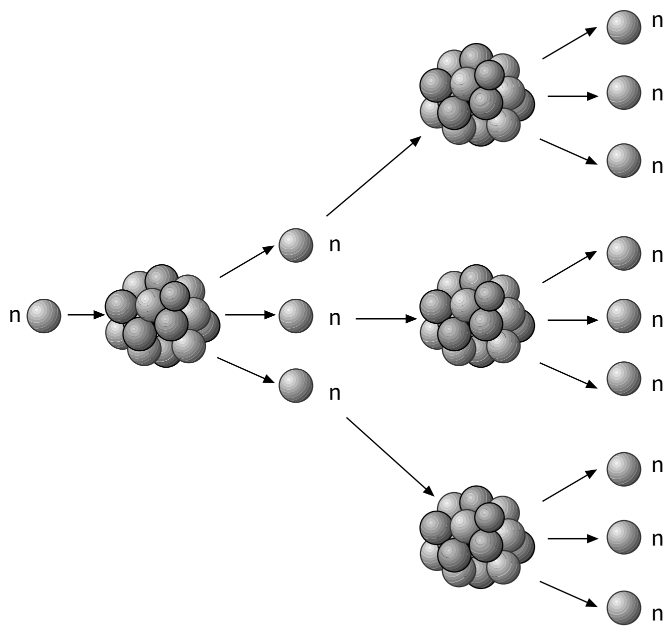

Nuclear fusion

Nuclear fusion is when ____ light nuclei join to make a heavier one.

Some of the ____ is converted to energy and transferred as radiation.

Nuclear fusion in the sun's core releases energy. A fusion ____ has to be at a very high temperature so the nuclei can overcome their ____.

Nuclear fusion in the future

Future fusion reactors could meet energy needs for a growing population. This is because:

- The fuel for fusion reactors is easily available as heavy ____ is naturally present in ____ ____.
- The product, ____, is an unreactive ____ and non-radioactive so is harmless.
- The energy released could be used to generate ____ in the future.

Key terms

Make sure you can write a definition for these key terms.

atom alpha activity atomic number background radiation beta chain reaction contamination count rate electron fission fusion gamma Geiger-Müller tube half-life ionisation irradiation isotope mass number net decline neutron plum pudding model proton peer review radiation dose radioactive decay spontaneous tracer

Chapter 7: Radioactivity

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

	P7 questions	Answers
1	Describe the basic structure of an atom.	
2	Describe the plum pudding model of the atom.	
3	What charges do protons, neutrons, and electrons carry?	
4	Why do atoms have no overall charge?	
5	What is the radius of an atom?	
6	What is ionisation?	
7	What is the mass number of an element?	
8	Which particle do atoms of the same element always have the same number of?	
9	What are isotopes?	
10	What were the two main conclusions from the alpha particle scattering experiment?	• •
11	What are the three types of nuclear radiation?	
12	Which type of nuclear radiation is the most ionising?	
13	What is the range in air of alpha, beta, and gamma radiation?	
14	What are the equation symbols for alpha and beta particles?	
15	What is meant by the half-life of a radioactive source?	
16	What is radioactive contamination?	
17	Where does background radiation come from?	
18	Why are gamma-emitting sources used for medical tracers and imaging?	
19	What is nuclear fusion?	
20	How does nuclear fission occur?	