BTEC Applied Science

Unit 1 Revision Guide

GET STARTED

How to use this guide

EXAM DATE:

Monday 5th June 2016, 9:00am, 1h 30m

This revision guide is divided into 3 sections; Biology, Chemistry and Physics. The contents page will take you to your chosen topic. To return to the contents page simply click the 'home' icon on the bottom right of the page.

When you have completed your revision for a topic, use the 'secure, unsure, weak' checkbox in the top right hand corner to record your progress. This will allow you to return to topics which need extra work.

Each revision page has some possible exam questions listed. When you have revised a topic you should complete these questions. Remember, practice makes perfect!

This guide is designed to help with your revision, it is not meant to replace your notes!

B

STRUCTURE AND FUNCTION OF CELLS AND TISSUE		Revised Y/N
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If using this document on a computer, click the page number to ring you to your chosen topic.

C

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P

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Keep track of your revision by marking off topics you have covered and high-lighting ones you have yet to revise.

B CELL THEORY

SECURE ☐ ☐ ☐

The cell is the fundamental unit of life. All organisms, whatever their type or size, are composed of cells. The modern theory of cellular organisation states:-

- All living things are composed of cells and cell products.
- New cells are formed only by the division of pre-existing cells
- The cell contains inherited information (genes), which is used as instructions for growth, functioning and development.
- The cell is the functioning unit of life; the metabolic reactions of life take place within the cells.

Robert Hooke

Eukaryotic	Prokaryotic
Eukaryotic cells make up multi-cellular organisms such as plants and animals. They are complex cells with a nucleus and membrane-bound organelles.	Prokaryotic cells are single-celled organisms. They are simple structures and do not have a nucleus or any membrane-bound organelles.
Plants and animals	Bacteria

MY NOTES:

1665:

Robert Hooke first described cells

1674–1683:

The first living cell was observed

Anton van Leeuwenhoek was the first person to observe bacteria and protoctista from pond water samples, after developing powerful glass lenses.

1831:

Nucleus observed

Robert Brown an English botanist was the first to observe and describe the nucleus in a plant cell.

1674–1683:

Universal cell theory

Matthias Schleiden suggested that all plant material is composed of cells. Jan Purkyne observed that animal tissue is composed of cells and the structure is similar to plant tissue. The scientist credited for the Universal Cell Theory is Theodor Schwann, a German physiologist. He proposed that 'all living things are composed of cells.

1852:

Evidence for the origin of new cells

Robert Remak observed cell division in animal cells. His findings were not accepted at the time, but in 1855 Rudolf Virchow published the findings as his own to show new cells form from existing ones.

1860:

Spontaneous generation disproved

Louis Pasteur demonstrated that bacteria will only grow in sterile nutrient broth after it has been exposed to air. This disproved the theory of spontaneous generation of cells.

Q:

1. Outline the similarities and differences between eukaryotic and prokaryotic cells.
2. Briefly outline how cell theory has developed over the past 400 years.

B MY NOTES/EXAM PRACTICE

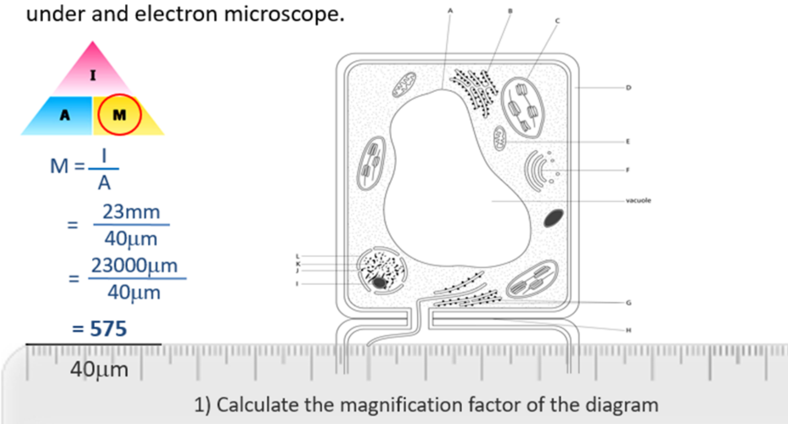
SECURE ☐

UNSURE ☐

WEAK ☐

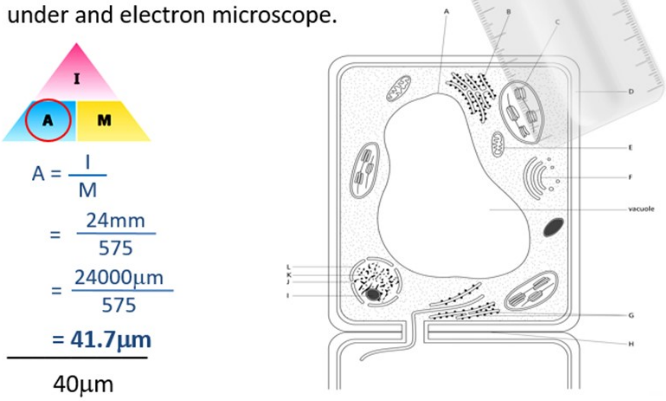
B MICROSCOPY

The diagram below shows the general structure of a plant cell when viewed under and electron microscope.



1) Calculate the magnification factor of the diagram

The diagram below shows the general structure of a plant cell when viewed under and electron microscope.



2) Calculate the length of structure C.

top tip

Show all of your working out in the exam, it is a good idea to draw the I AM triangle and complete it with figures.

SECURE ☐

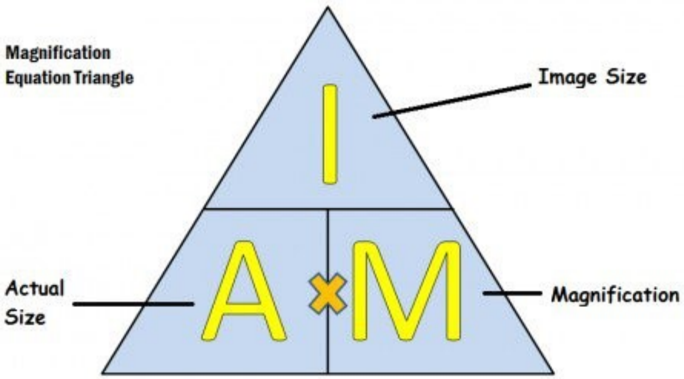
UNSURE ☐

WEAK ☐

Light Microscopy	Electron Microscopy
Light microscopes use visible light and magnifying lenses to observe small objects.	They use a beam of electrons in a vacuum with a wavelength of less than 1 nm to visualise the specimen.
Positive: can observe sub-cellular structures.	Positive: x500000 magnification, high resolution (0.1nm) electron micrographs produced
Limitations: lower magnification (x500) and resolution (x200nm)	Limitations: destroys the sample

We can use the equation below to calculate magnification:

Magnification = Size of Image (I) ÷ Actual Size (A)



Q:

1. The actual length of the mitochondrion in the animal cell is 10.0 µm. Calculate the magnification of the nucleus in the image to the left.
2. A microbiologist measures an electron micrograph image of a bacterium to be 4.5 cm in length. The magnification used to view the bacterium was 22 500x. Calculate the actual size of the bacterium.

B MY NOTES/EXAM PRACTICE

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B ANIMAL CELLS

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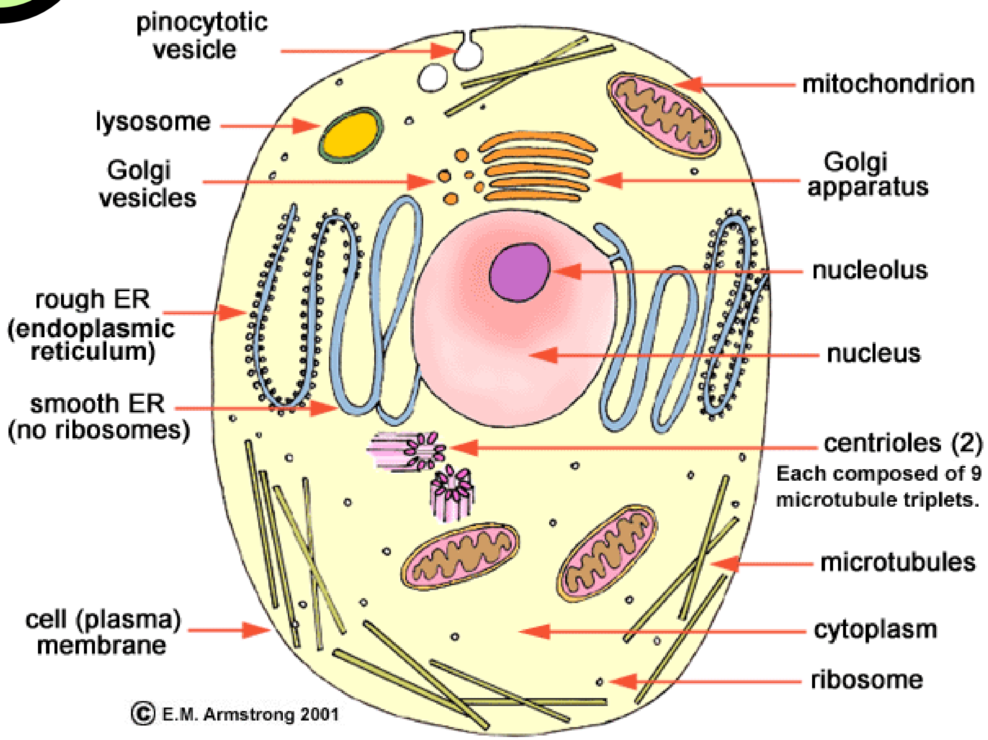
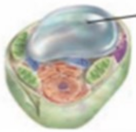


One of the key **functions** of a cell is to synthesise proteins for use inside the cell, to lead to cell multiplication and for secretion out of the cell for example, insulin.

- Proteins are synthesised on ribosomes attached to rough endoplasmic reticulum.
- The newly synthesised proteins are transported through the cisternae of the rough ER and packaged into vesicles.
- They are transported to the Golgi apparatus, where vesicles fuse with the surface of the Golgi apparatus and the proteins enter.
- It is here that the newly synthesised proteins are modified and then packaged into vesicles. Secretory vesicles will transport proteins that are to be released from the cell to the cell surface membrane.
- They will fuse with the membrane and release the protein by **exocytosis**.

 **Nucleus** the organelle that contains the cell's DNA and is the control center of the cell	 **Chloroplast** the organelle that uses the energy of sunlight to make food
 **Ribosome** the organelle in which amino acids are hooked together to make proteins	 **Golgi complex** the organelle that processes and transports proteins and other materials out of cell
 **Endoplasmic reticulum** the organelle that makes lipids, breaks down drugs and other substances, and packages proteins for Golgi complex	 **Large central vacuole** the organelle that stores water and other materials
 **Mitochondrion** the organelle that breaks down food molecules to make ATP	 **Lysosome** the organelle that digests food particles, wastes, cell parts, and foreign invaders

top tip

Make sure you can link the structure of a cell organelle with its function.

Q:

1. State **two** functions of the Golgi apparatus.
2. Draw from memory a labelled diagram of an animal cell.
3. Outline the functions of each cell component.

B MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

B PLANT CELLS

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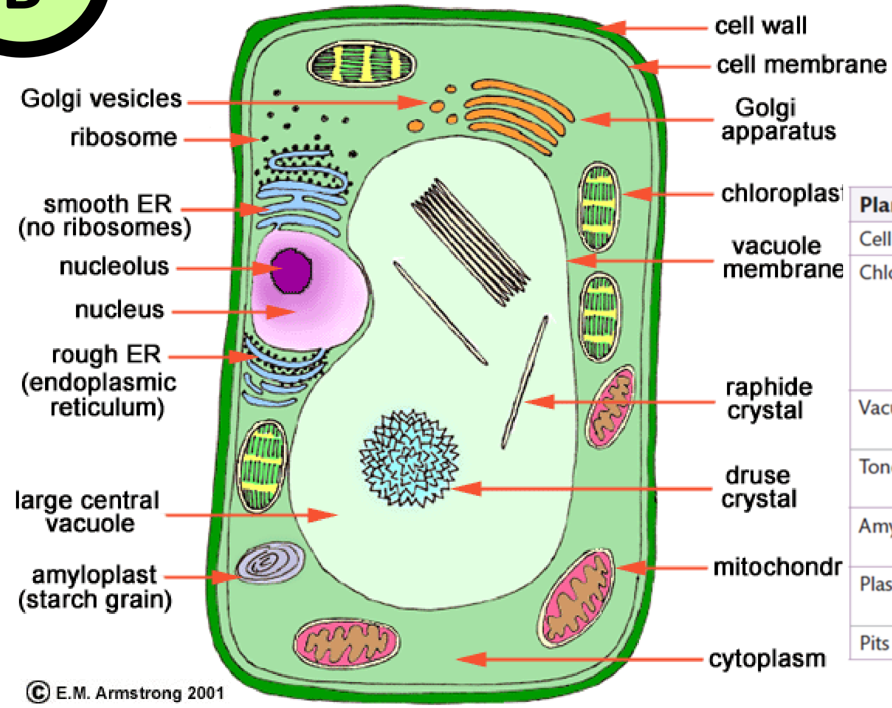
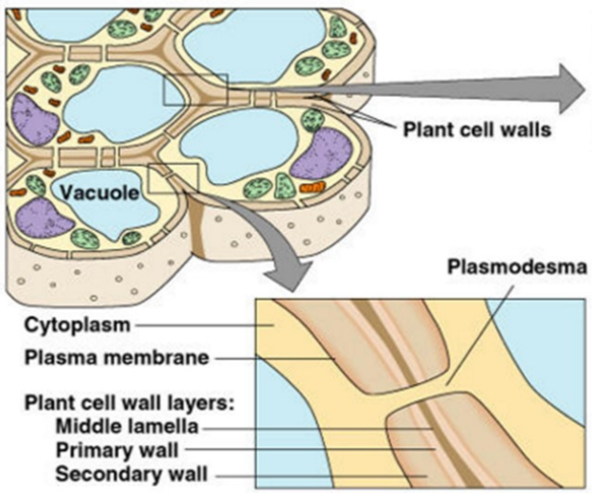


Plant cell structure	Structure	Function
Cell wall	Made of cellulose forming a sieve like network.	Protects and supports each cell and the whole plant.
Chloroplast	Has a double membrane and is filled with a fluid called stroma. The inner membrane is a continuous network of flattened sacs called thylakoids. A stack of thylakoids is called a granum (grana is plural). Grana contain chlorophyll pigments.	Site of photosynthesis. Light energy is trapped by the chlorophyll and used to produce carbohydrate molecules from water and carbon dioxide.
Vacuole	Membrane bound sac in cytoplasm that contains cell sap.	Maintain turgor to ensure a rigid framework in the cell.
Tonoplast	The partially permeable membrane of the vacuole.	Selectively permeable to allow small molecules to pass through.
Amyloplast	A double membrane bound sac containing starch granules.	Responsible for the synthesis and storage of starch granules.
Plasmodesmata	Microscopic channels which cross the cell walls of plant cells.	Enable transport and communication between individual plant cells.
Pits	Pores in the cell walls of the xylem.	Allow water to enter and leave xylem vessels.



MY NOTES:

Plasmodesma: Microscopic channels which cross the cell walls of plant cells. Enable transport and communication between individual plant cells.

Q:

1. Name an organelle found in a plant cell that is not present in this animal cell.
2. Outline the function of each plant cell component.

top tip

Make sure you can link the structure of a cell organelle with its function.

B MY NOTES/EXAM PRACTICE

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UNSURE ☐

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B BACTERIA CELLS

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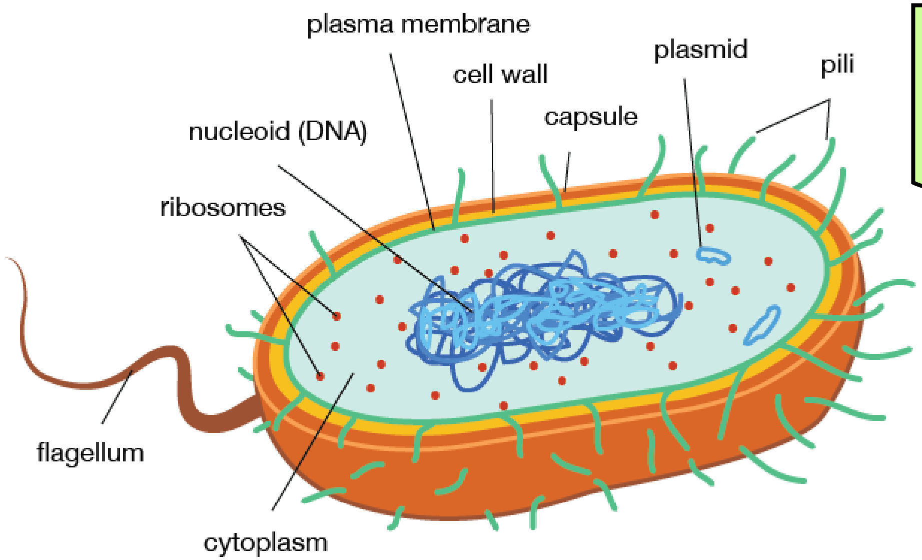


Bacterial cells, like many other animals and plants, produce and secrete toxins that have an effect on other organisms.

- DNA is free in the cytoplasm of a prokaryotic cell in the area called the nucleoid.
- A section of DNA containing a genetic code for a metabolve unwinds and hydrogen bonds break.
- RNA nucleotides line up (**complementary base pairing**). Messenger **RNA** is formed. This process is known an **transcription.**
- The next process is the production of the bacterial protein. This is called **translation** and it occurs at the ribosomes.
- Transcription and translation can occur simultaneously because the genetic material is free in the nucleoid surrounded by ribosomes.
- The newly made protein toxin is moved to the surface membrane ready to be secreted to cause infection.

Note that many bacteria are beneficial to humans and to eukaryotes.

Organelle	Structure	Function
Cell wall	Prokaryotic cells are surrounded by a cell wall made of peptidoglycan.	Protects and supports each cell.
Capsule	Slippery layer outside the cell wall of some species of bacteria.	Protects the cell and prevents dessication.
Ribosomes	Smaller than ribosomes found in eukaryotic cells. They consist of two sub-units and they are not surrounded by a membrane.	Protein synthesis occurs at the ribosomes.
Nucleoid	The nucleoid (meaning nucleus-like) is the irregularly-shaped region that holds nuclear material without a nuclear membrane and where the genetic material is localized. The DNA forms one circular chromosome.	The nucleoid is the region where generic information can be found. and controls cellular activity.
Plasmid	Small circular loops of DNA.	Plasmids carry genes that may benefit the survival of the organism.

top tip

Make sure you can link the structure of a cell organelle with its function.

Ribosome size is determined by their ability to form sediment in a solution. Eukaryotic ribosomes are determined as 80S whereas prokaryotic cell ribosomes are smaller and are 70S.

Q:

1. Name the type of ribosome found in bacteria.
2. Explain how the ultrastructure of a bacterium capsule prevents dehydration.

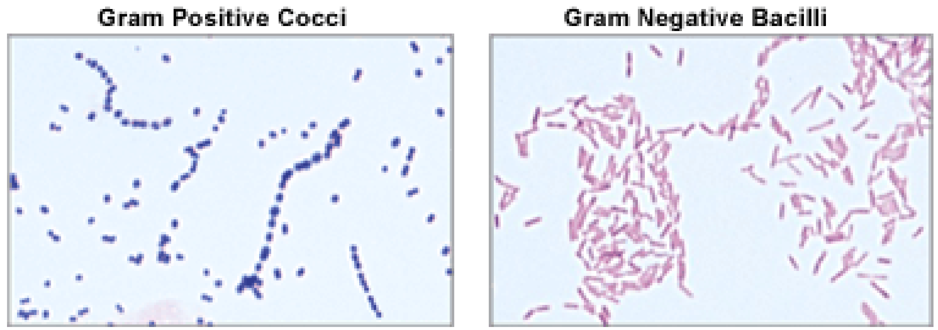
B MY NOTES/EXAM PRACTICE

SECURE ☐
UNSURE ☐
WEAK ☐

B GRAM STAINING

SECURE ☐
UNSURE ☐
WEAK ☐

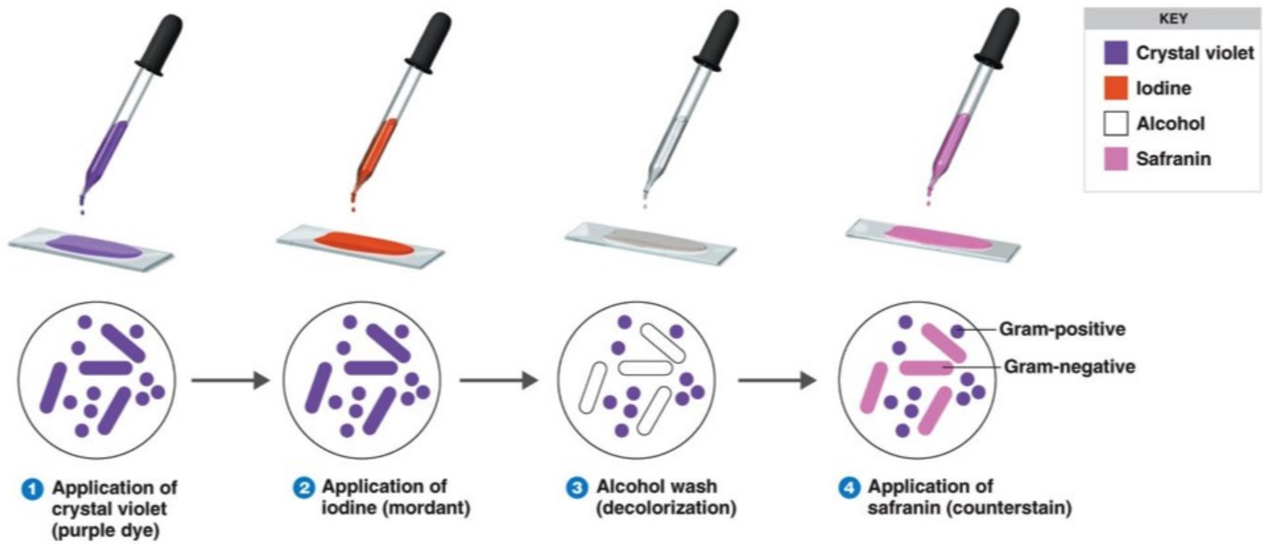
It is important that microbiologists can correctly identify bacteria that cause infections to enable them to decide the most effective treatment.



Color and shape of the cells help classify which type of bacteria are present.
Used with permission of AAFP-PT.

During the staining technique, two stains are added to the bacterial smear: crystal violet and safranin.

Gram Positive	Gram Negative
If you see a purple stain when observing the smear under a microscope it shows that Gram-positive bacteria are present.	If the smear has retained the pink safranin stain, this shows that Gram-negative bacteria are present. This is because their thinner cell walls and lipid membranes allow ethanol (applied during the method) to wash off all the crystal violet purple stain and to then retain the pink safranin stain.



Q:

1. Briefly explain how to carry out gram staining.

B MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

B SPECIALISED CELLS (I)

SECURE ☐
UNSURE ☐
WEAK ☐

<table>
<tr><th>Palisade mesophyll cells</th><th>Root hair cell</th><th>Sperm cell</th></tr>
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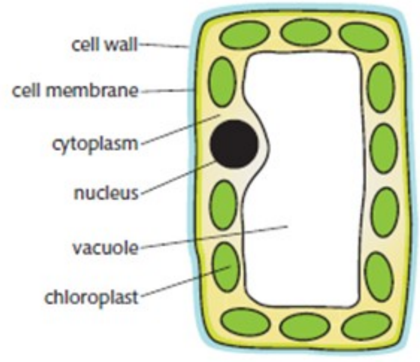
<td>
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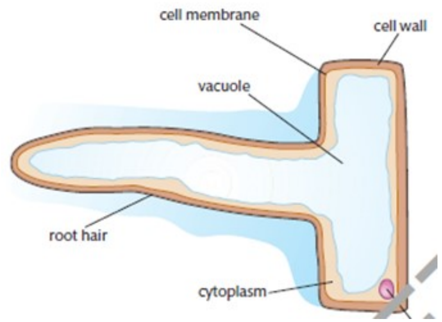
<td>
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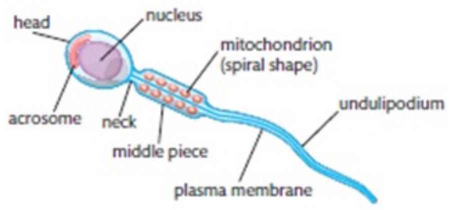
<td>
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<tr>
<td>Palisade mesophyll cells found in leaves are rectangular box shaped cells that contain chloroplasts. The chloroplasts are able to absorb a large amount of light for photosynthesis. They also move around in the cytoplasm in order to maximise the amount of light absorbed.</td>
<td>These cells are found at a plant's roots, near the growing tip. They have long hair-like extensions called root hairs. The root hairs increase the surface area of the cell to maximise the movement of water and minerals from the soil into the plant root.</td>
<td>Sperm cells are male gametes in animals. They have a tail like structure called a undulipodium so they can move. They also contain many mitochondria to supply the energy needed for this movement. The sperm head is 3 µm wide and 4 µm long. It is made up of an acrosome, which contains digestive enzymes. These enzymes are released when the sperm meets the egg, to digest the protective layer and allow the sperm to penetrate. The sperm's function is to deliver genetic information to the egg cell or ovum (female gamete). This is fertilisation</td>
</tr>
</table>

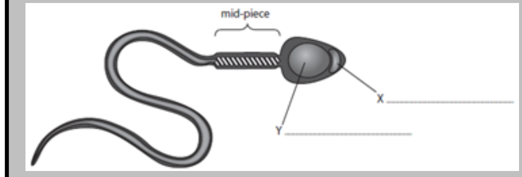
top tip

Do you understand the meaning of the key terms 'gametes' and 'water potential'?

MY NOTES:

Q:

Scientists researching fertilisation in humans need to understand how sperm cells are adapted for their specific function. The diagram shows a human sperm cell. Complete the missing labels, X and Y, on the diagram.



1. Explain how the mid-piece of a human sperm cell is specialised to support the function of its tail.

B

MY NOTES/EXAM PRACTICE

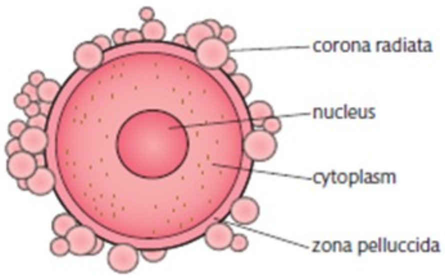
SECURE ☐

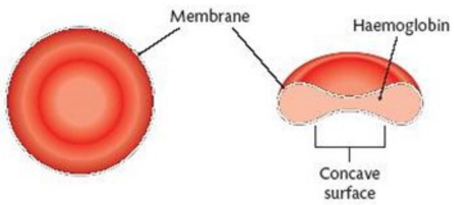
UNSURE ☐

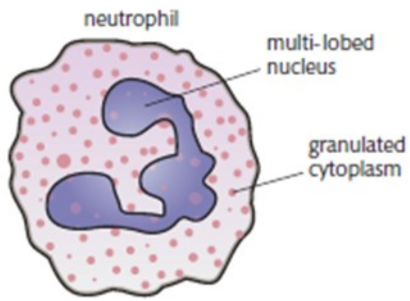
WEAK ☐

B SPECIALISED CELLS (II)

SECURE ☐
UNSURE ☐
WEAK ☐







Egg cells	Red Blood cells	White blood cell
Egg cells, or ova, are the female gametes in animals. An egg cell is one of the largest cells in the human body, and is approximately 0.12 mm in diameter. It contains a nucleus which houses the genetic material. The zona pellucida is the outer protective layer/membrane of the egg. Attached to this is the corona radiata, which consists of two or three layers. Its function is to supply proteins needed by the fertilised egg cell.	Red blood cells or erythrocytes are a bi-concave shape. This increases the surface area to volume ratio of an erythrocyte. They are flexible so that they can squeeze through narrow blood capillaries. Their function is to transport oxygen around the body. In mammals, erythrocytes do not have a nucleus or other organelles. This increases space for the **haemoglobin** molecules inside the cell that carry oxygen.	Neutrophils are a type of white blood cell and they play an important role in the immune system. They have multi-lobed nuclei, which enables them to squeeze though small gaps when travelling to the site of infection. The cytoplasm holds lysosomes that contain enzymes that are used to digest **pathogens** that are ingested by the neutrophil.

MY NOTES:

Q:

1. Explain how the shape of red blood cells allows them to carry out their function.
2. What is the function of neutrophils?

top tip

Do you understand the meaning of the key terms 'pathogen and 'Haemoglobin' ?

B MY NOTES/EXAM PRACTICE

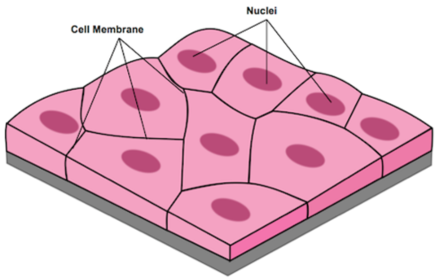
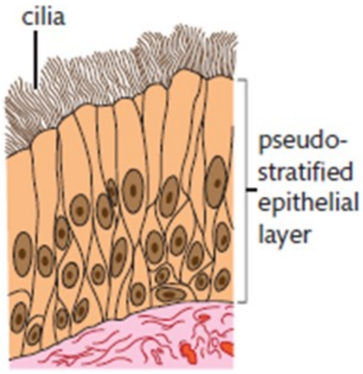
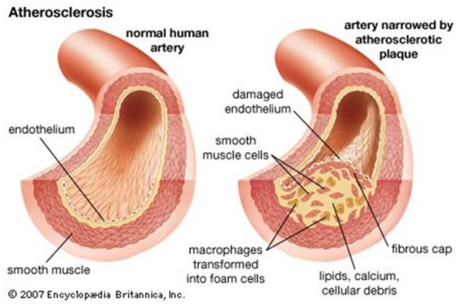
SECURE ☐

UNSURE ☐

WEAK ☐

B EPITHELIAL TISSUE

SECURE ☐
UNSURE ☐
WEAK ☐

Squamous epithelial tissue	Ciliated columnar epithelial tissue	Endothelial tissue
		
Location: lines organs and surfaces	**Location:** line the trachea in the respiratory system, column-shaped **ciliated cells** with hair-like structures called cilia covering the exposed cell surface	**Location:** found lining the heart, blood vessels and lymphatic vessels
Function: one cell thick, form thin, smooth, flat layers. Ideal for rapid diffusion e.g. alveoli in lungs - rapid diffusion of oxygen	**Function:** protect the lungs from infection by sweeping away pathogens and secreting mucus to trap pathogens	**Function:** The cells provide a short diffusion pathway for the movement of various substances, such as: • products of digestion into blood capillaries • blood plasma and tissue fluid in and out of blood capillaries.
Damage caused by smoking: Smoking irritates and causes inflammation and scarring in the epithelium tissue of the lungs. The alveoli walls become thicker due to scarring and produce more mucus. The damage to the air sacs causes emphysema and the lungs lose their natural elasticity.	**How the lungs are protected:** They secrete mucus to help trap any unwanted particles that are present in the air that you breathe in. This protects your lungs because it prevents bacteria reaching the alveoli.	**How arteriosclerosis develops:** Carbon monoxide and high blood pressure can damage the inner lining of the arteries. White blood cells repair the damage and encourage the growth of smooth muscle and the deposition of fatty substances such as cholesterol under the endothelium lining of arteries, not on the surface. This process of deposition is called atherosclerosis

MY NOTES:

Q:

1. What is the name of the lung tissue that contains ciliated cells?

A columnar endothelium

B columnar epithelium

C squamous endothelium

D squamous epithelium

2. Chemicals in cigarette smoke reduce the movement of the cilia on ciliated cells in the human lung. Explain how reducing the movement of these cilia can result in a smoker having to cough.

B MY NOTES/EXAM PRACTICE

SECURE ☐
UNSURE ☐
WEAK ☐

B MUSCLE TISSUE (I)

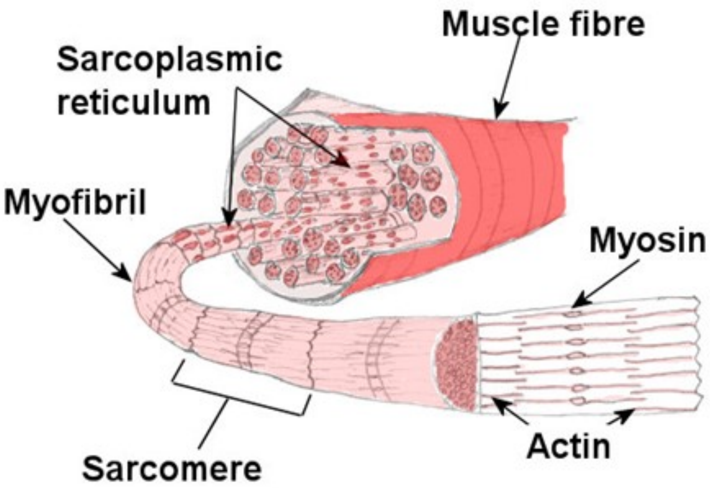
Muscles are composed of cells that are elongated and form fibres. Muscle cells contain protein filaments called actin and myosin that enable muscles to contract and cause movement. There are three types of muscle tissue:

- **Skeletal** muscle is found attached to bones. You can control its contraction and relaxation, and it sometimes contracts in response to reflexes.
- **Cardiac** muscle is found only in the heart. It contracts at a steady rate to make the heartbeat. It is not under voluntary control.
- **Smooth** muscle is found in the walls of hollow organs, such as the stomach and bladder. It is also not under voluntary control.

SECURE ☐

UNSURE ☐

WEAK ☐



MY NOTES:

Q:

1. Heart disease caused by atherosclerosis is a major problem in the UK. Smoking cigarettes and drinking alcohol are lifestyle factors that increase the risk of atherosclerosis. State **one** other lifestyle factor that increases the risk of atherosclerosis.

Skeletal Muscle Fibre:

- Muscle tissue needs to be able contract (shorten in length) in order to move bones.
- In a muscle, cells join up to make muscle fibres. These are long strands of cells sharing nuclei and cytoplasm, which is known as the sarcoplasm.
- Inside the muscle cell cytoplasm are many mitochondria, specialised endoplasmic reticulum known as sarcoplasmic reticulum and a number of microfibrils.
- Each muscle fibre is surrounded by a cell surface membrane called the **sarcolemma**.
- Skeletal muscle shows a stripy/banding appearance under a microscope.
- Skeletal muscle is made up of thousands of muscle fibres. Each muscle fibre is made up of myofibrils

B

MY NOTES/EXAM PRACTICE

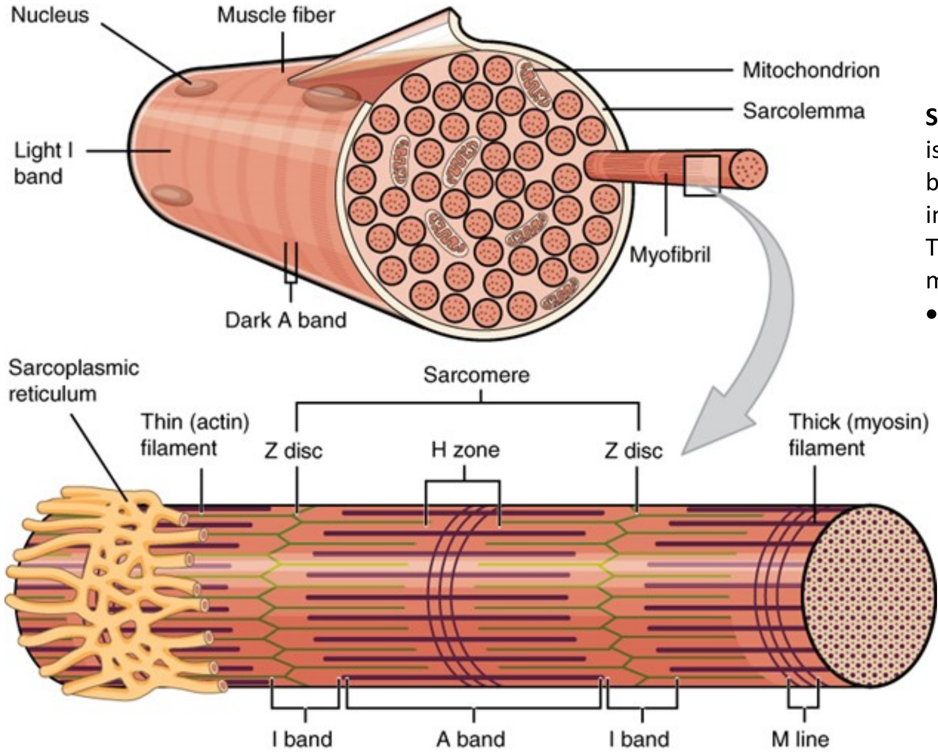
SECURE ☐

UNSURE ☐

WEAK ☐

B MUSCLE TISSUE (II)

SECURE ☐
UNSURE ☐
WEAK ☐



Sarcomere: The span from one z-line to the next is known as the sarcomere. When the muscle is relaxed, this is approximately 2.5 μm in length. This length reduces when the muscle contracts because the I-band and H-zone lengths are reduced. The A-band does not change in length during contraction.

There are two protein filaments found in muscle cells. This filament made of actin and thick filaments made of myosin.

- During muscle contraction, the thin actin filaments move and overlap the thick myosin filaments. The sarcomere shortens, decreasing the size of the overall muscle.

Slow Twitch Muscle Fibres	Fast Twitch Muscle Fibres
Slow twitch muscles are more effective at using oxygen to generate energy in the form of ATP, for continuous and extended muscle contractions over a long time. These fibres help marathon runners and endurance cyclists to continue for hours. Slow twitch fibres have:	Fast twitch oxidative muscle fibres are similar in structure to slow twitch muscle fibres. They contain many mitochondria, myoglobin and blood capillaries, but they are able to **hydrolyse** ATP much more quickly and therefore contract quickly. They are relatively resistant to fatigue.
• less sarcoplasmic reticulum • more mitochondria for sustained contraction • more myoglobin • a dense capillary network • these fibres release ATP slowly by **aerobic respiration**.	**Fast twitch glycolytic muscle fibres** have relatively less myoglobin, few mitochondria and few capillaries. They contain a large concentration of **glycogen** that provides fuel for **anaerobic respiration**. They contract rapidly but also fatigue.

Q:

1. A young athlete is very good at long-distance running but is not good at sprinting. Discuss how this difference relates to the types of muscle fibre in his legs.
2. Name the **two** myofilaments found in a skeletal muscle fibre that give it its striated appearance.
3. Explain the function of the sarcoplasmic reticulum in skeletal muscle tissue.

B MY NOTES/EXAM PRACTICE

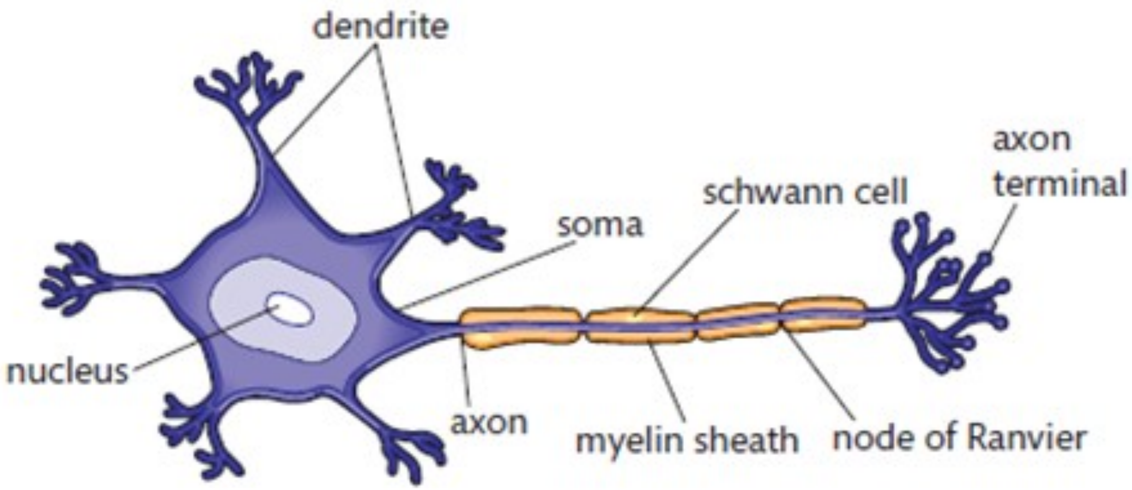
SECURE ☐

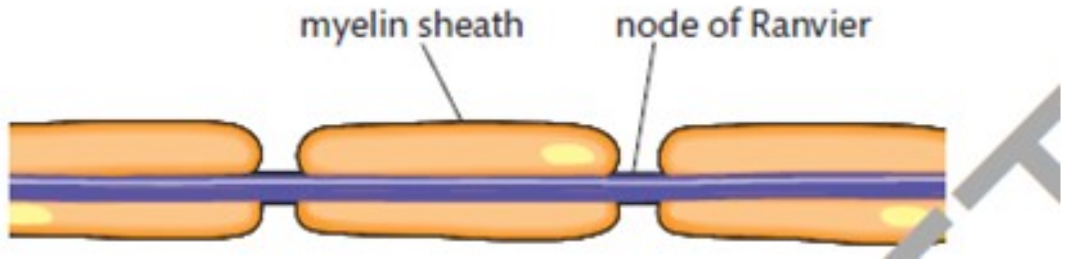
UNSURE ☐

WEAK ☐

B NERVOUS TISSUE (I)

SECURE ☐
UNSURE ☐
WEAK ☐





- The central nervous system (CNS) consists of the brain and spinal cord. It is made up of billions of non-myelinated nerve cells and longer, myelinated axons (axons with myeline sheath) and **dendrons** that carry nerve impulses. Nervous tissue is made of nerve cells called neurons.

- Neurons are cells that receive and facilitate nerve impulses, or action potentials, across their membrane and pass them onto the next neuron. They consist of a large cell body called a soma with small projections called dendrites and an axon. The end of the axon is called the axon terminal. It is separated from the dendrite of the following neuron by a small gap called a synapse.

Resting Potential	Action Potential
Resting potential is the term given to a neuron that is not transmitting an action potential and is at rest.	Fast twitch oxidative muscle fibres are similar in structure to slow twitch muscle fibres. They contain many mitochondria, myoglobin and blood capillaries, but they are able to **hydrolyse** ATP much more quickly and therefore contract quickly. They are relatively resistant to fatigue.

Q:

1. The table shows the speed of a nerve impulse in different types of axon of the same diameter.

Speed of nerve impulse/ms^{-1}	
Myelinated axon	Unmyelinated axon
25	5

Explain the difference in the speed of the nerve impulse along these axons.

2. Explain how hyperpolarisation occurs in an axon cell.

top tip

There are several topics covered in nervous tissue. Take time to study them carefully.

B MY NOTES/EXAM PRACTICE

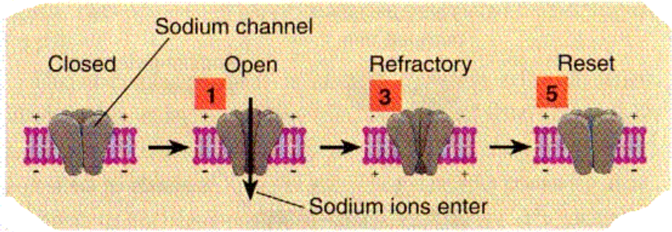
SECURE ☐

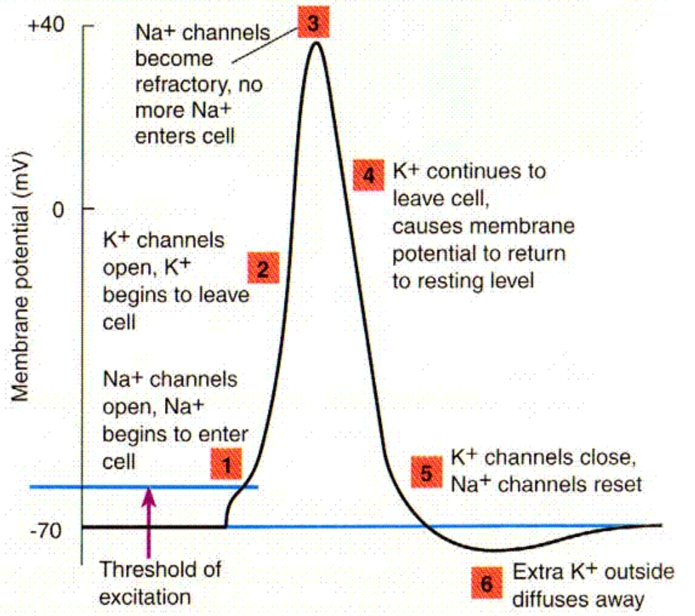
UNSURE ☐

WEAK ☐

B NERVOUS TISSUE (II)

	Resting and Action Potential
1	Nerve impulses are ionic imbalances that travel from one end of a neuron to the other because of a potential difference.
2	When a neuron is at rest, the inside of the cell is negatively charged relative to the outside.
3	Sodium-potassium channels pumping Na^+ ions to the outside of the cell and K^+ ions into the cell. The resting potential is approximately **-70mV.**
4	When a stimulus is applied, an action potential occurs.
5	Sodium channels open and the sodium ions flood into the cell. The positive sodium ions cause the resting potential of the cell to decrease – this is call **depolarisation**.
6	Once +40mV is reached, the Na^+ channels close and the K^+ channels open. K^+ floods out of the cell and the charge goes back down – this is called **repolarisation**.
7	This process of depolarisation and repolarisation continues and the action potential moves all the way down the neuron.
8	To continue its journey through the nervous system, the signal needs to start an action potential in the next neuron. The two neurons will not be in direct contact, and the action potential cannot 'jump' across the synaptic cleft (gap).
9	As the action potential reaches the end of the first neuron, Ca^{2+} channels are opened and Ca^{2+} flows into the cell.
10	This induces vesicles containing neurotransmitters to fuse with the presynaptic membrane, and the neurotransmitters diffuse across the synaptic cleft.
11	The neurotransmitters move across the synapse and bind to complimentary receptors in the postsynaptic membrane.
12	This triggers the opening of Na^+ channels, which causes depolarisation of the membrane and the start of a new action potential in the second neuron.
13	The neurotransmitters are then actively absorbed back into the original neuron, or an enzyme is released to break them down, stopping them from generating continuous action potentials.





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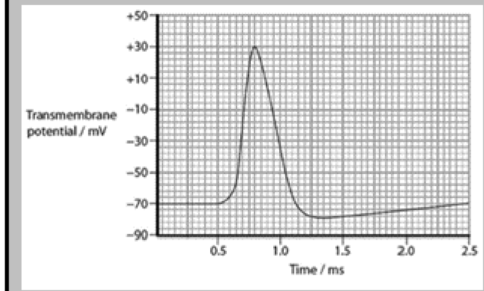
UNSURE ☐

WEAK ☐

Q:

1. Nerve impulses are important in the control of many activities in the human body. The graph shows changes in the transmembrane potential during the transmission of a nerve impulse along the axon of a motor neurone. State the time period when depolarisation is taking place.



top tip

Spend some time on learning this. Make sure you can explain the graph above fully, it has appeared on sample papers.

B

MY NOTES/EXAM PRACTICE

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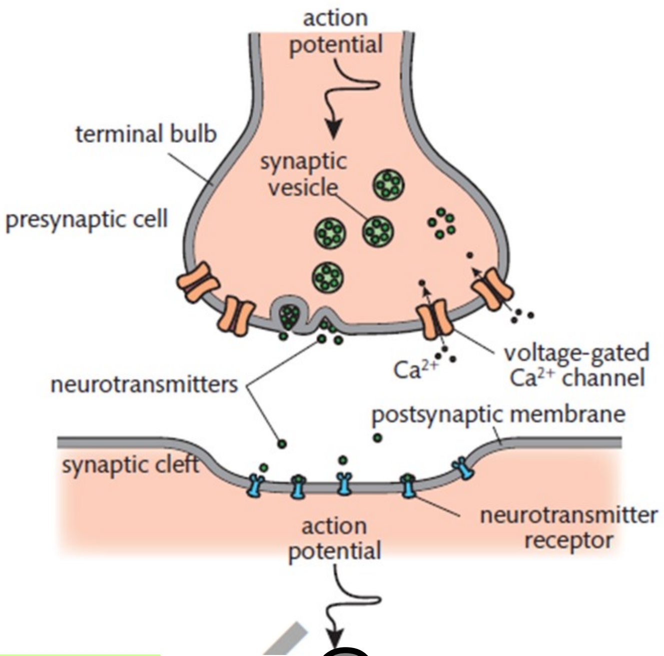
WEAK ☐

B NERVOUS TISSUE (III)

SECURE ☐
UNSURE ☐
WEAK ☐

Synapses

- When the nerve impulse reaches the end of the neuron, it must cross a gap called a synapse to get to the next neuron or the effector cell.
- A nerve impulse crosses the synapse in the form of a chemical transmitter called a neurotransmitter.
- Neurotransmitters diffuse across the synapse and initiate an action potential in the neuron at the other side. The presynaptic neuron ends in a swelling called the synaptic bulb and it contains many mitochondria as ATP is needed.
- The neurotransmitters are stored in temporary vesicles in the synaptic bulb that can fuse with the surface to release the neurotransmitters into the synapse.
- They also contain voltage-gated calcium ion channels.



Problems that can occur:

Parkinson's disease is a **genetic** disease that affects the nervous system. Parkinson's sufferers are not able to produce the naturally occurring chemical dopamine, a neurotransmitter that helps smooth and normal movements. Without this, people show symptoms of:

- slow movement
- speech problems
- tremors when moving
- poor balance

The drug, L-dopa, replaces the dopamine that is lost in people with Parkinson's disease. Serotonin is another of the body's naturally occurring neurotransmitters. It is normally active in the brain and can cause problems if it is not produced. Some forms of depression are caused by a reduced amount of serotonin in the brain.

top tip

Practice drawing a synapse and labelling each step showing how an action potential crosses.

Q:

Nerve impulses are transmitted across synapses by neurotransmitters. The diagram shows what happens to a neurotransmitter called acetylcholine in the synaptic cleft.

acetylcholine —(cholinesterase enzyme)→ acetate + choline

Organophosphates are chemicals that prevent the cholinesterase enzyme working. When they are used as crop pesticides they can kill the small animals that feed on the crops.

1. Explain how these pesticides kill small animals.

B MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

C ELECTRONIC STRUCTURE

SECURE ☐
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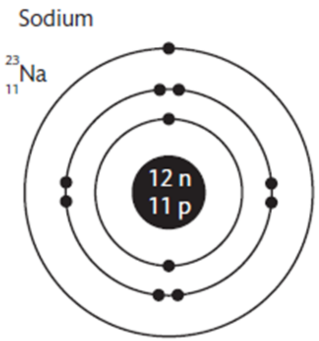
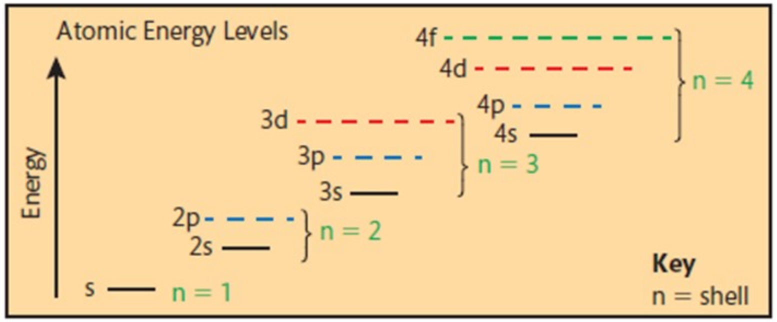
WEAK ☐



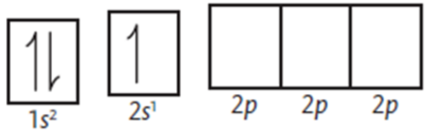
Electron shell	Maximum number of electrons
1	2
2	8
3	18
4	32
5	50



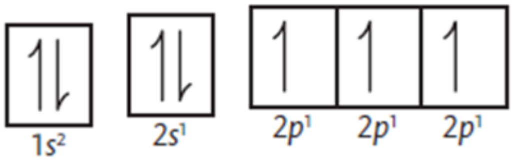
- Electrons within each shell will not have the same amount of energy and so the energy levels or shells are broken down into subshells called **orbitals.** These are called s, p, d and f orbitals. The orbitals have different energy states.
- The Aufbau principle states that electrons fill the orbital with the lowest available energy state in relation to the proximity to the nucleus before filling orbitals with higher energy states. This gives the most stable **electron configuration** possible.
- **Spin** – electrons have two possible states, 'spin up' and 'spin down'. In an orbital, each electron will be in a different 'spin state'.

Half arrows are used to represent each electron in the orbitals. They are drawn facing up and down as each electron in an orbital will have a different spin

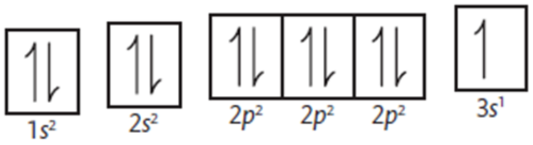
1. The electrons sit in orbitals within the shell. Each orbital can hold up to two electrons.	4. The third shell consists of 1 s-type orbital, 3 p-type orbitals and 5 d-type orbitals.
2. The first shell can hold 2 electrons in a s-type orbital.	5. Electrons fill the lowest energy level orbitals first.
3. The second shell consists of 1s-type orbital and 3 p-type orbitals.	6. Where there are several orbitals of exactly the same energy (e.g. the 3 2p orbitals of the second shell), the electrons will occupy different



Lithium (3 electrons)



Nitrogen (7 electrons)



Sodium (11 electrons)

Q:

1. Which of the following elements has this electronic structure?

1s2 2s2 2p2

A Boron

B Carbon

C Oxygen

D Sulfur

2. Explain the arrangement of the electrons in the third energy level of silicon.

3. Explain why the first ionisation energy of silicon (789 kJ mol–1) is greater than that of germanium (762 kJ mol–1).

top tip

Recap the basic structure of an atom from KS4, be able to draw the electronic configuration of atoms.

C MY NOTES/EXAM PRACTICE

SECURE ☐

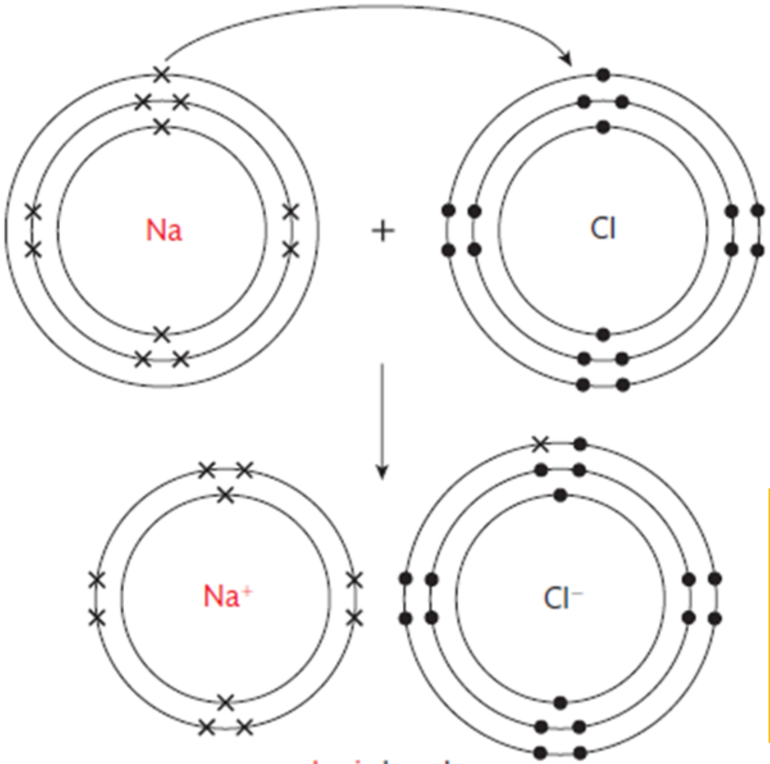
UNSURE ☐

WEAK ☐

C IONIC BONDING

SECURE ☐
UNSURE ☐
WEAK ☐

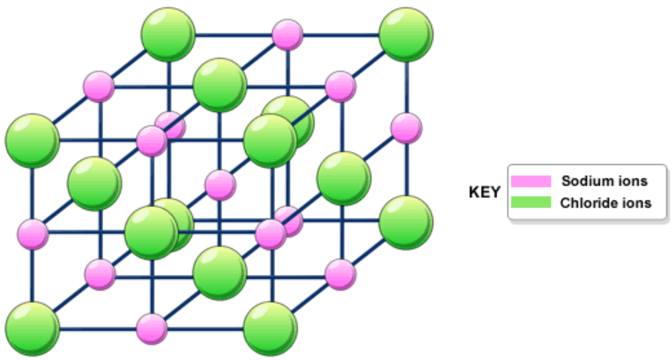
- **Ionic bonding** occurs when an atom of an element loses one or more electron and donates it to an atom of a different element.
- The atom that loses electrons becomes **positively charged** and the atom that gains electron(s) become **negatively charged** because of the imbalance of protons and electrons.



Ionic bond

- Ions containing more than one element can also be formed. For example, in sodium hydroxide, Na+ bonds with the hydroxide ion $(OH)^-$.
- The opposite charges on the ions are what hold them together. This is **electrostatic attraction**.
- **Electrostatic attraction:** the force experienced by oppositely charged particles. It holds the particles strongly together.

MY NOTES:



- The opposite charged ions in sodium chloride form a **giant ionic lattice** where the ions are arranged in a regular pattern.
- The strength of the electrostatic force and, therefore, of the ionic bond is dependent on the **ionic charge** and the **ionic radii** of the ions.
- The more electrons a positive ion has, the more shells it will have. If an ion has more shells, then its radius will be bigger than an ion with fewer shells.
- The electrostatic force is stronger when the ionic charge is higher.

top tip

You should be able to show the bonding in NaCl, NaF, Li_2O, Li_3N and MgO.

Q:

The production of the ionic compound calcium chloride is an important industrial process. Calcium chloride has a large range of uses, for example in the pharmaceutical industry and in the food industry.

1. State the name of the force between the calcium and chloride ions.
2. Draw dot-and-cross diagrams to show the arrangement of the outer electrons in the calcium ion and the two chloride ions in calcium chloride, $CaCl_2$.

Draw dot and cross diagrams to show the arrangement of the **outer** electrons in the magnesium ion and the two chloride ions in magnesium chloride, $MgCl_2$.

C

MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

C COVALENT BONDING

Covalent bonding usually occurs between atoms of two non-metals. A covalent bond forms when an electron is shared between the atoms. These electrons come from the top energy level of the atoms.

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UNSURE ☐
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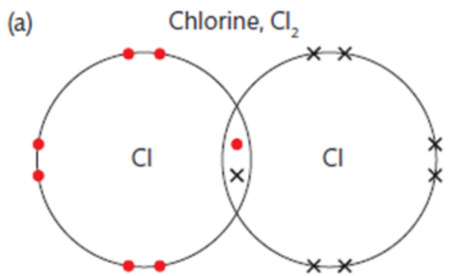
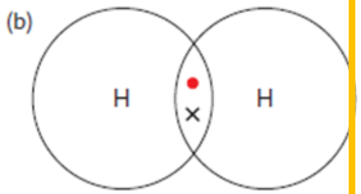
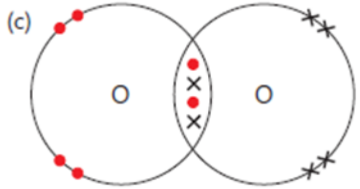




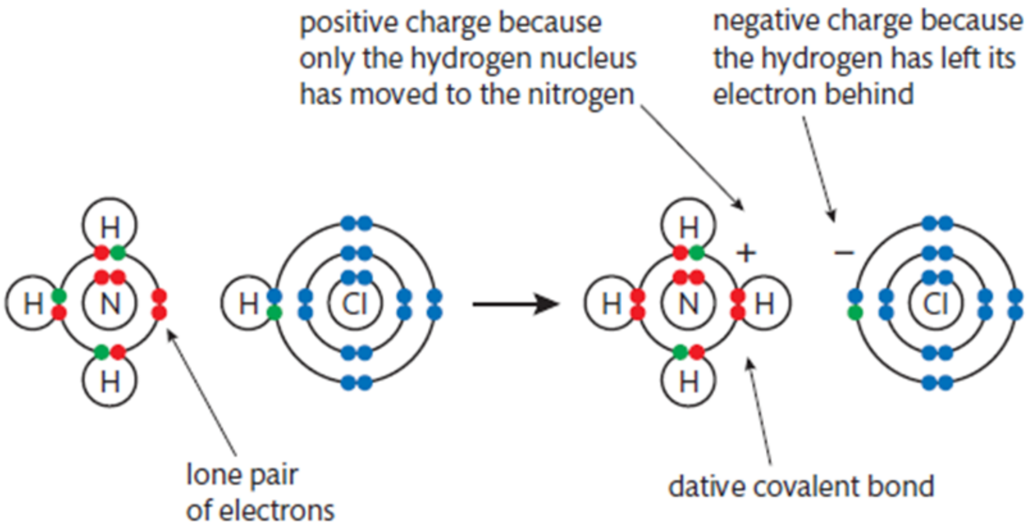


In some covalent molecules, both sharing electrons come from one atom. This is called a **dative (coordinate) covalent bond.**
Covalent bonds can be formed when atoms share more than one pair of electrons, e.g. oxygen atoms. The double bonds between the oxygen are formed by two shared pairs of electrons

MY NOTES:

Lone Pairs: A lone pair is a non-binding pair of electrons.

An ammonium ion contains a dative bond. When ammonia reacts with hydrochloric acid, a hydrogen ion from the acid is transferred to the ammonia molecule. A **lone pair** of electrons on the nitrogen atom forms a dative covalent bond with the hydrogen ion.

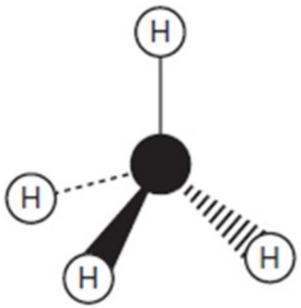


Q:

1. Using dot and cross diagrams, show covalent bonding between two oxygen atoms and in hydrochloric acid.

Organic compounds – a compound that contains one or more carbons in a carbon chain.

- Carbon makes four covalent bonds so it forms many compounds which are called **organic compounds**.
- Methane has the formula CH_4. Each carbon atom bonds covalently with four hydrogen atoms.
- These four bonds mean that methane is not a flat molecule. It has a tetrahedral structure. This is because the bonds are as separated from each other as possible, because the negative electron pairs repel each other, with each bond angle being 109.5°.



top tip

You should be able to show the bonding in CH_4, O_2, Cl_2, N_2.

C

MY NOTES/EXAM PRACTICE

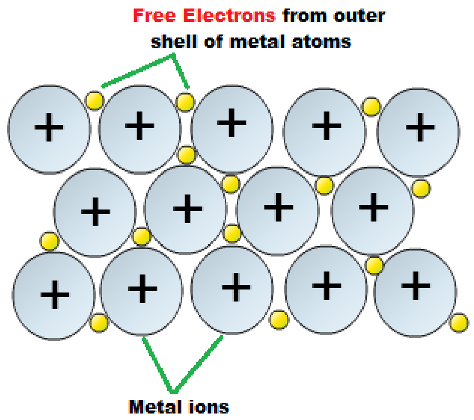
SECURE ☐

UNSURE ☐

WEAK ☐

C METALLIC BONDING

- Metals are giant structures of atoms held together by metallic bonds. The metal structure is a regular lattice.
- Metallic bonding is caused because the electrons in the highest energy level of a metal atom has the ability to become **delocalised**.
- They are free to move through the metal in a 'sea' of electrons.
- This gives the metal nuclei a positive charge which is attracted to the negative charge on the delocalised electrons.
- There is a very strong force of attraction between the positive metal nuclei and the negative delocalised electrons.



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Nonpolar covalent bonding

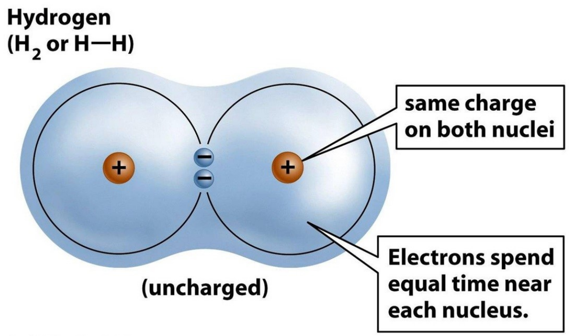

Figure 2-6a Biology: Life on Earth, 8/e
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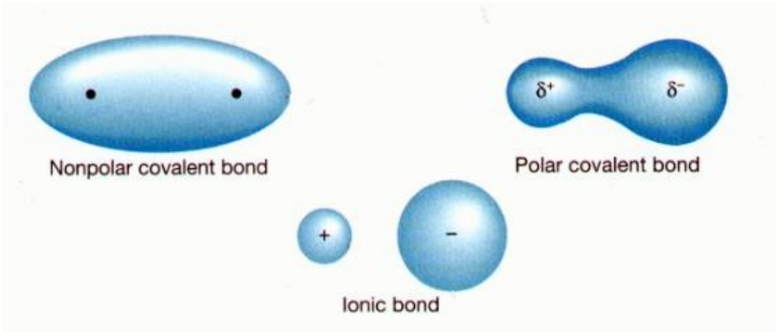
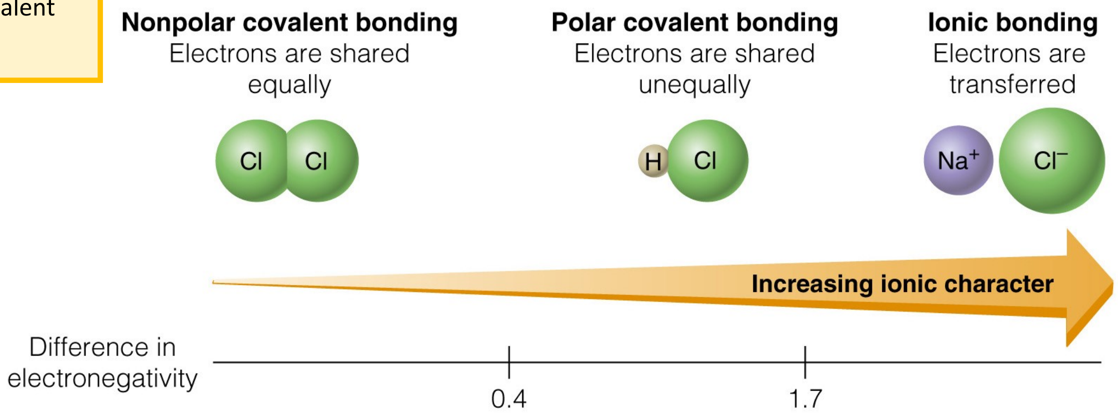
Non-polar molecule – a molecule where the electrons are distributed evenly throughout the molecule. E.g. covalent bonding in chlorine.
Polar molecule – a molecule with partial positive charge in one part of the molecule and similar negative charge in another part due to an uneven electron distribution.



MY NOTES:

Electronegativity– This is the tendency of an atom to attract a bonding pair of electrons. Atoms that have similar electronegativities form covalent bonds.



Q:

1. Metallic bonding is caused because the electrons in the highest energy level of a metal atom has the ability to become **delocalised**. What do you understand by the term 'highest energy level'?
2. Draw a full labelled diagram and write a paragraph to explain metallic bonding.

top tip

Make sure you can explain the term 'sea of electrons'.

C MY NOTES/EXAM PRACTICE

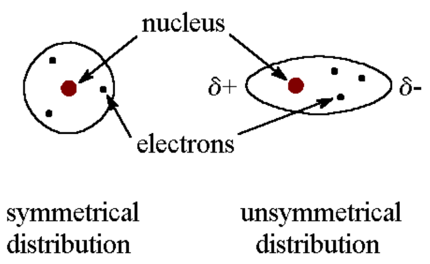
SECURE ☐

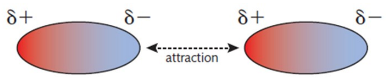
UNSURE ☐

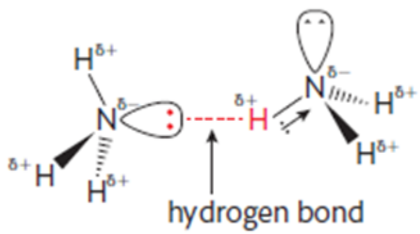
WEAK ☐

C INTERMOLECULAR FORCES

London Dispersion Forces	Dipole-dipole Forces	Hydrogen Bonding
• London dispersion forces are also called **temporary dipole** – induced dipole forces. • They are weak forces present between non-polar covalent molecules. • When the electron distribution in a molecule becomes non-symmetrical (i.e. there are more electrons at one end of the molecule than the other) then one end of the molecule can become more positive and one end can become more negative. • This causes a temporary dipole. The positive and negative charge in the dipole can disturb the electrons in a nearby molecule, repelling the electrons and so causing (inducing) a dipole in that molecule. • The molecule with the temporary dipole and the molecule with the induced dipole attract each other and pull the molecules together.	• These are permanent forces between polar molecules. • Polar molecules have a permanent negative end and a permanent positive end. • These oppositely charged end attract each other. • Dipole-dipole forces are slightly stronger than London dispersion forces but are still weak in comparison to a covalent bond. • Molecules that have permanent dipole-dipole forces include hydrogen chloride, HCl, and iodine monochloride, ICl.	• The strongest form of intermolecular force. • These are a special type of dipole-dipole bond and are forces that are about 10% the strength of a covalent bond. • Hydrogen bonds will form when compounds have hydrogen directly bonded to fluorine, oxygen or nitrogen. • When two of these molecules are close together, there will be an attraction between the positive end of one and the lone pair of electrons of the other. This is a hydrogen bond. • This is different to other dipole-dipole forces because there are inner bonding electrons. • The single electron in the hydrogen atom is drawn to the nitrogen, oxygen or fluorine atom.







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WEAK ☐

Intermolecular forces – the attraction or repulsion between neighbouring molecules. All intermolecular attractions are van der Waals forces.

Q:

Nitrogen(IV) oxide is a gas which dissolves in water in the atmosphere to form

acid rain.

Electronegativity of nitrogen 3.006

Electronegativity of oxygen 3.610

1. Explain the **two** types of intermolecular force that exist in nitrogen(IV) oxide.

C

MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

C QUANTITIES USED IN CHEMISTRY (I)

SECURE ☐
UNSURE ☐
WEAK ☐

Balancing Equations

There are several different methods to balance a chemical equation. Your teacher may have shown you a different method from the one described below. Use whichever method suites you best!

$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

	Balancing Chemical Equations	
1	Split the equation in half by drawing a line through the arrow.	$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
2	Circle each element individually to make them easier to count (remember to circle the numbers after each ele-	$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
3	Now count the number of atoms on the left and compare with the right. If the numbers match place a tick above them.	√ √ √ $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$ In this case, only the oxygen balance as there are 3 on the left and 3 on the right.
4	Now starting ADDING atoms so that the equation balances. Remember if you add 1 atom in a molecule, you must add the entire molecule.	√ √ √ $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$ O_2 CO_2 H_2O O_2 H_2O
5	Now count up everything you have added and place the total number in front.	√ √ √ $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$ O_2 CO_2 H_2O O_2 H_2O x3 x2 x3
6	Rewrite the final equation with final numbers.	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 2H_2O$

Q:

Aluminium corrodes quickly in air to form a thin protective aluminium oxide layer that prevents further oxidation. This protective layer makes it suitable for use in drink cans.

1. Write the balanced equation for the reaction of aluminium in air to form aluminium oxide.

top tip

Use a technique to balance equations that you are familiar with.

C MY NOTES/EXAM PRACTICE

SECURE ☐
UNSURE ☐
WEAK ☐

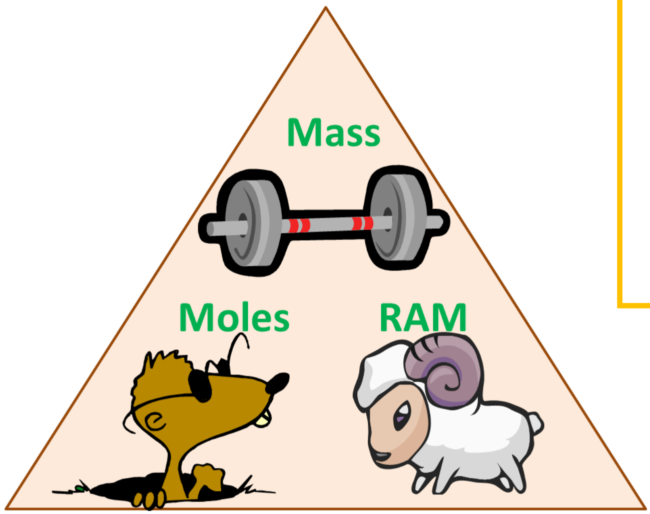
C QUANTITIES USED IN CHEMISTRY (II)

SECURE ☐
UNSURE ☐
WEAK ☐

Moles, Molar Masses and Molarities

- Chemical equations allow you to work out the masses of the reactants you need to use in order to get a specific mass of product.
- One mole of a chemical means there are 6.023×10^{23} particles (Avogadro's constant).
- A mole is the amount of a substance which has the same number of particles as there are atoms in 12 g of carbon-12.
- So one mole of carbon dioxide has the same number of particles as one mole of gold. The **molar mass** of a substance is equal to the mass of one mole of a substance.
- **Mole = Mass ÷ M_r**

A_r	M_r
The relative atomic mass (A_r) of an element on the periodic table tells you how much mass there is in one mole of the **element**.	The relative formula mass is the sum of all the relative atomic masses of all the atoms in the empirical formula (simplest formula) of a **compound** (M_r).
E.g. A_r of H = 1 A_r of O = 16	E.g. M_r of H_20 = (1x2)+16=18 M_r of O_2 = 2x16=32



MY NOTES:

What is the number of moles in 20 g of sodium hydroxide, NaOH?
Number of moles = mass/*Mr*
For sodium hydroxide *Mr* = 23 + 16 + 1 = 40
Number of moles = 20÷40= 0.5 moles

What is the number of moles in 136.5 g of potassium?
Number of moles of an element = mass/*Ar*
For potassium *Ar* =39
Number of moles = 136.5÷39= 3.5 moles

top tip

Practice makes perfect when calculating moles. You will find plenty of exercises online to improve your skills.

Q:

1. Calculate the number of moles (to 2dp) in…

A. 13g of Na

B. 26g of Mg

C. 46g of Ca

2. Calculate the mass of …

A. 2 moles of Li

B. 3.5 moles of C

C. 0.3 moles of S

C

MY NOTES/EXAM PRACTICE

SECURE ☐
UNSURE ☐
WEAK ☐

C QUANTITIES USED IN CHEMISTRY (III)

SECURE ☐
UNSURE ☐
WEAK ☐

Empirical Formula	Molecular Formula
This shows the ratio between elements in a chemical compound. It is useful when discussing giant structures such a sodium chloride. The empirical formula of a compound can be calculated from the masses of each element in the compound.	Molecular formulae are used for simple molecules. To work out the molecular formula you need to know the empirical formula and the relative molecular mass.

Suppose 3.2g of sulfur reacts with oxygen to produce 6.4g of sulfur oxide. What is the formula of the oxide?

Use the fact that the A_r of sulfur is 32 and the A_r of oxygen is 16.

Steps to calculation the formula of a compound

step	action	S	O
1	find masses	3.2	3.2
2	look up given A_r values	32	16
3	divide masses by A_r	0.1	0.2
4	find the ratio	1	2

Result: the formula for the oxide = SO_2

E.g the **empirical formula** of a hydrocarbon is CH_2 and its M_r is 42.

- the mass of the atoms in the empirical formula is 14
- 42 ÷ 14 = 3
- so you need to multiply the numbers in the empirical formula by 3

The **molecular formula** of the hydrocarbon is therefore C_3H_6.

Example: A compound contains 75% carbon and 25% hydrogen. What is its empirical formula?

	C	H
Amount	75	25
Convert to moles (/M_r)	/12 = 6.25	/1 = 25
Calculate mole ratio (divide by smallest number)	6.25/ 6.25	25/6.25
	= 1	= 4
Empirical formula	C	H_4

MY NOTES:

Q:

1. An oxide of carbon contains 27% carbon and 73% oxygen. What is its empirical formula?

2. Fluorspar is made of calcium and fluorine. If 51% is calcium, calculate the empirical formula.

3. 1.68g of iron is combined with 0.48g of oxygen. What is the empirical formula of the new compound?

top tip

You will find several worksheets and worked examples for this topic online.

C MY NOTES/EXAM PRACTICE

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WEAK ☐

C QUANTITIES USED IN CHEMISTRY (IV)

Number of moles (*N*) = **molarity** (*C*) x **volume of solution** (*V*) (dm^3)

N = CV

How many moles of hydrochloric acid are there in 100 cm^3 of 1M hydrochloric acid solution?

Number of moles (*N*) = molarity (*C*) x volume of solution (*V*) (dm^3)

N = CV

The volume is given in cm^3 so this needs to be converted into dm^3 by dividing by 1000. (Remember 1 dm^3 = 1000 cm^3)

number of moles = $\frac{100}{1000}$ x 1

= 0.1 mol

What is the concentration of a sample of sodium hydroxide solution if 10 dm^3 contains 0.5 mol?

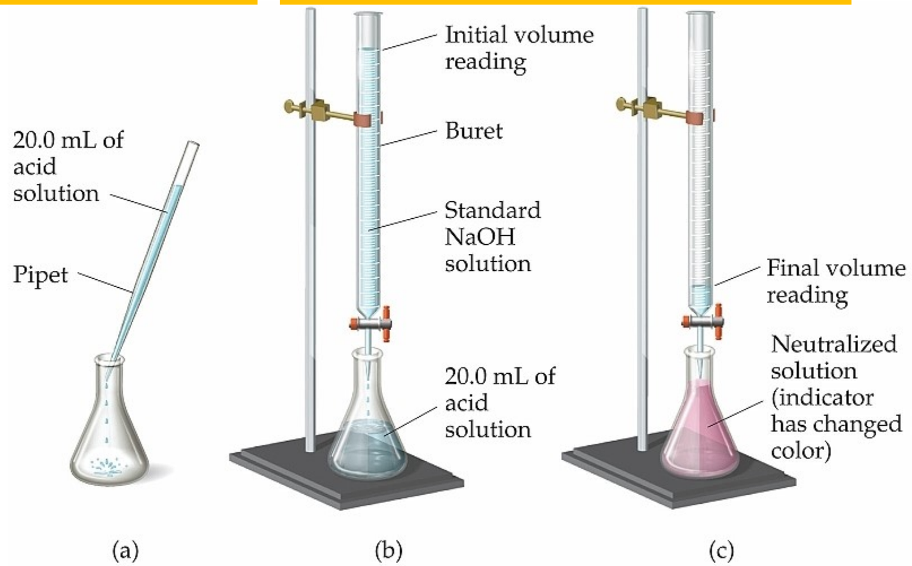
Number of moles (*N*) = molarity (*C*) x volume of solution (*V*) (dm^3)

N = CV

0.5 = *C x* 10

C = $\frac{0.5}{10}$

= 0.05M



top tip

Look at the diagram to the right, can you outline the steps involved in a titration?

KEYWORDS

Titration – a method of volumetric analysis used to calculate the concentration of a solution.
Solution –a liquid mixture where a solute is dissolved in a solvent
Standard solution – a solution of known concentration used in volumetric analysis.
Solute – the substance dissolved in a solvent to form a solution.
Solvent - a liquid that dissolves another substance.

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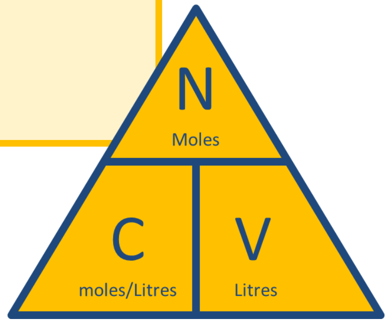

Q:

1. What volume in cm^3 of 2M sulfuric acid solution would you need to ensure you had a sample containing 0.05 mol?

2. Calculate the number of moles of HCl in 20 cm^3 of a 2 mol dm^{-3} solution of HCl(aq).

C

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C QUANTITIES USED IN CHEMISTRY (V)

Stoichiometry – involves using the relationships between the reactants and the products in a chemical reaction to work out how much product will be produced from given amounts of reactants.

Calculate the expected mass of calcium chloride produced when 50 g of calcium carbonate is reacted with excess hydrochloric acid.

Ar (H) = 1, *Ar* (C) =12, *Ar* (0) = 16, *Ar* (Cl) = 35.5, *Ar* (Ca) = 40

One mole of $CaCO_3$ produces one mole of $CaCl^2$.
You know this from the balanced equation

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$.

This shows a one to one (1:1) ratio.

Add up the relative atomic masses for each compound.
40 +12 + (3x16) g = 100 g of $CaCO_3$ produces 40 + (35.5x2) g = 111 g of $CaCl_2$.

As one mole of $CaCO_3$ produces one mole of $CaCl_2$ then
100 g $CaCO_3$ produces 111 g $CaCl_2$.
In this case, only 50 g of $CaCO_3$ was used so

50 g $CaCO_3$ produces $\frac{111}{100}$ x 50 g $CaCl_2$.
50 g $CaCO_3$ produces 55.5 g $CaCl_2$.

You could say that only $\frac{1}{2}$ a mole of $CaCO_3$ was used so therefore only half the amount of $CaCl_2$ would be produced and this would give the same answer of 55.5 g.
This is the theoretical mass.

STATE SYMBOLS

A solid substance is indicated by **(s)**
A solution is indicated by **(aq)**
A liquid is indicated by **(l)**
A gas is indicated by **(g)**

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MY NOTES:

top tip

Video Clip: https://www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome/stoichiometry-ideal/v/

Theoretical mass – the expected amount of product from a reaction calculated from the balanced equation.
Percentage yield – the actual amount of yield worked out as a percentage of the theoretical yield.

The formula for calculating percentage yield is:

$$\text{Percentage yield} = \frac{\text{actual number of moles}}{\text{expected number of moles}} \times 100\%$$

It can also be calculated as:

$$\text{Percentage yield} = \frac{\text{actual mass}}{\text{theoretical mass}} \times 100\%$$

Q:

1. Calculate the expected mass of water if 10 g of oxygen is reacted with excess hydrogen.
2. When 50 g of calcium carbonate is reacted with excess hydrochloric acid solution to make calcium chloride, the theoretical yield is 55 g. When the reaction was carried out, only 44 g of calcium chloride was produced. Calculate the percentage yield of calcium chloride.

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C

THE PERIODIC TABLE

Period 1: Contains hydrogen and helium. Both are gases. The electrons in these two elements fill the 1*s* orbital. Helium only has two electrons and, chemically, helium is unreactive. Hydrogen readily loses or gains an electron, and so can behave chemically as both a group 1 and a group 7 element. Hydrogen can form compounds with most elements and is the most abundant chemical element in the universe.

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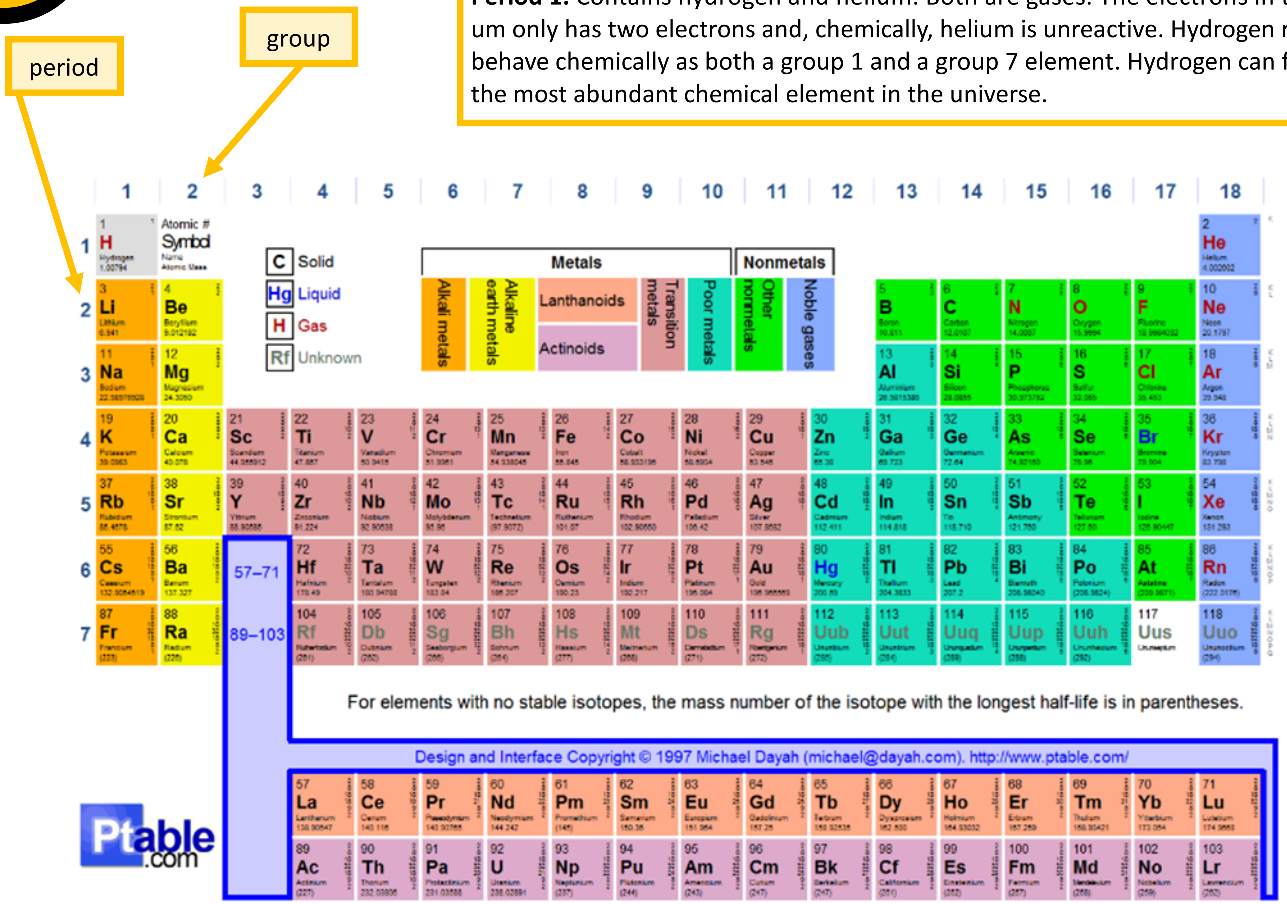

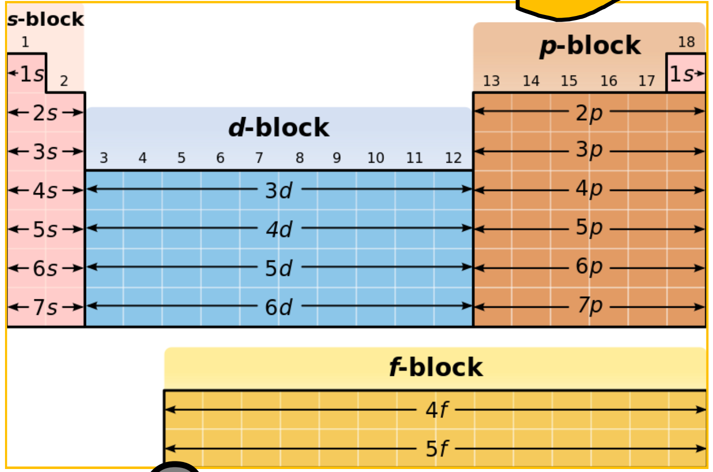

Q:

1. Explain why calcium is an s block element.
2. An element has the electronic configuration 1s2 2s1 Identify which period the element is in.
3. Complete the electronic configuration for an atom of sodium.

$1s^2, 2s^2$,.....

Period 2: Contains eight elements, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine and neon. The outer electrons in these elements fill the 2*s* and 2*p* orbitals. Nitrogen, oxygen and fluorine can all form diatomic molecules. Neon is a noble gas. Carbon is a giant molecular structure.

Period 3: Contains eight elements, sodium, magnesium, aluminium, silicon, phosphorus, sulfur, chlorine and argon. The outer electrons in these elements fill the 3*s* and 3*p* orbitals.

Period 4: Contains 18 elements, from potassium to krypton. The first row of the transition elements is in this period. The outer electrons on these elements fill the 4*s*, 4*p* and 3*d* orbitals.

C MY NOTES/EXAM PRACTICE

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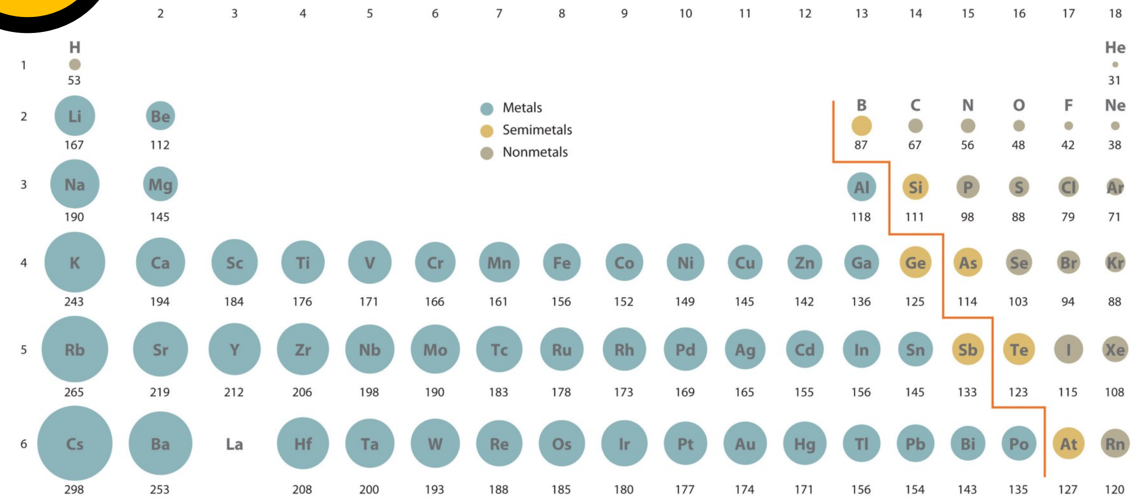
C PHYSICAL PROPERTIES OF ELEMENTS (I)



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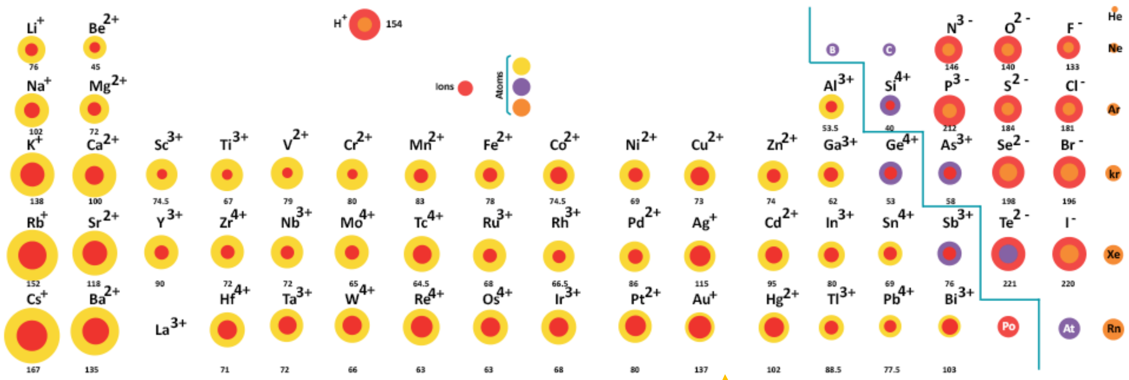
Atomic Radius: The radius of an atom changes depending on what is around it.

- **The atomic radius decreases across the period from left to right**. Across the group, more protons and electrons are added. However, the extra electrons are added to the same s and p sub-shells and so the size does not increase. The extra protons increase nuclear charge. The increased nuclear charge attracts the extra electrons and pulls them closer to the nucleus. This leads to a decrease in atomic radius.
- **As you go down a group the atomic radii increases.** This is because the extra electrons are added to additional shells and so the radius increases. Although nuclear charge increases, the number of inner shells increases and so the nuclear charge is shielded more. This means that the atomic radius increases.



KEYWORDS

Isoelectronic – having the same numbers of electrons.

Cations – ions with a positive charge.

Anions – ions with a negative charge.

Q:

1. Explain the trends in atomic radius as you move across a period from left to right.
2. Outline the trends in the ionic radii of cations and anions moving across a period from left to right.

Ionic Radius: The trends in ionic radius down a group follow a similar pattern to the trend for atomic radius down a group. This is because extra electrons are added to extra shells as you go down the group therefore giving a larger size.

- **Cations** have a smaller radius than their corresponding atom. As you go across a period, the cations all have the same electronic structure. They are **isoelectronic**, therefore although number of electrons remains the same, the nuclear charge increases, for example, Na+, Mg2+, A3+. However, the number of protons increases across the period. This pulls the electrons more strongly to the centre of the ion so the ionic radii of the cations decreases as you go across the period.
- **Anions** have a larger radius than the corresponding atom because there is more repulsion between the extra electrons. As you go across the period, the anions are all isoelectronic, for example, N3–, O2–, F–. They have more electrons not fewer. The number of protons still increases as you go across the period whilst the number of shells and electrons stays the same so the ionic radius of the anions also decreases as you go across the period.

C MY NOTES/EXAM PRACTICE

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C PHYSICAL PROPERTIES OF ELEMENTS (II)

Electronegativity is a measure of the tendency of an atom to attract a bonding pair of electrons. It increases as you go across a period. It decreases as you go down a group.

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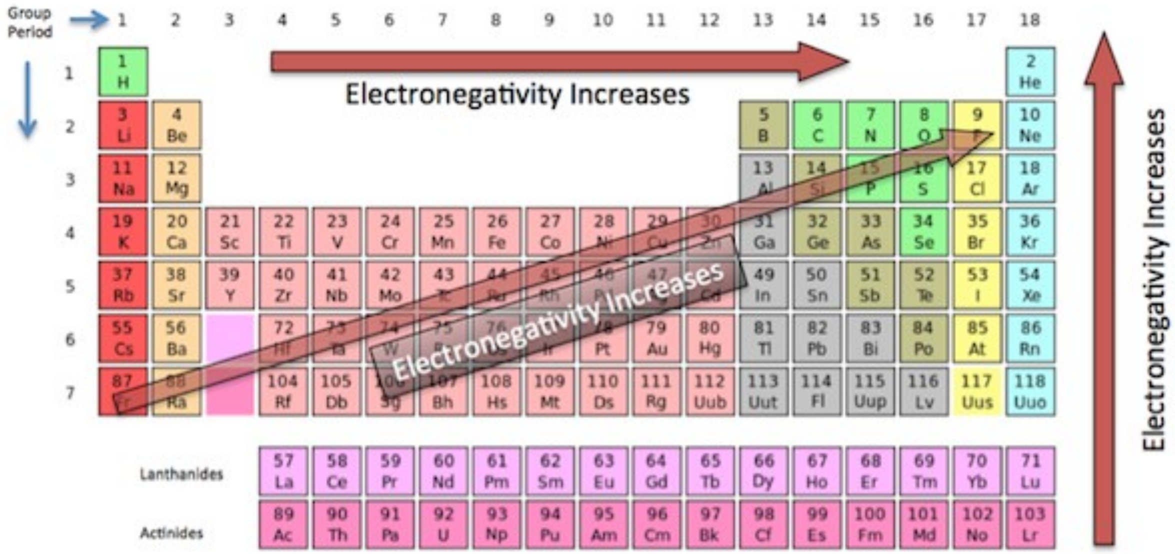


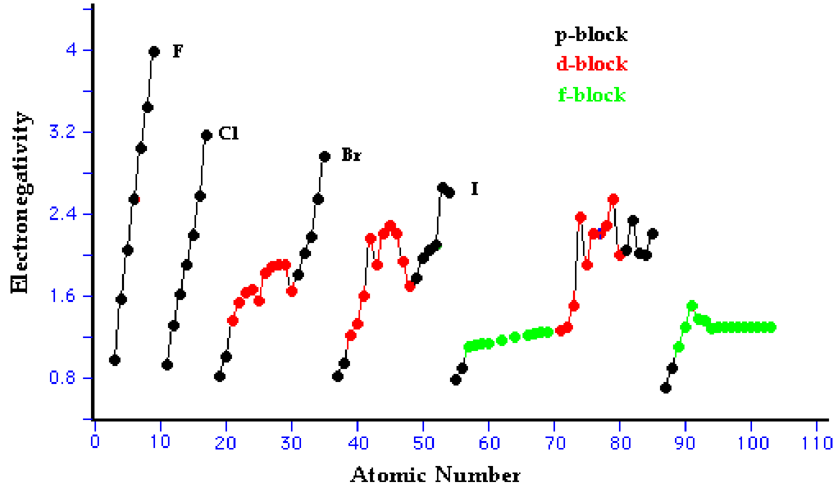
Electronegativity Trend

Fluorine is the most electronegative element

Electronegativity depends on:

- the number of protons in the nucleus
- the distance from the nucleus of the bonding pair of electrons
- how much shielding there is from inner electrons

The Group 0 gases such as argon that do not form bonds do not have electronegativity that can be reliably determined, because they do not form compounds/bonds.



top tip

Make sure you can interpret the graph to the right and explain why electronegativity changes.

Q:

1. State the meaning of the term electronegativity.
2. Describe the trends in electronegativity in the periods and groups of the periodic table.
3. State the **three** factors that affect the electronegativity of an element.

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C PHYSICAL PROPERTIES OF ELEMENTS (III)

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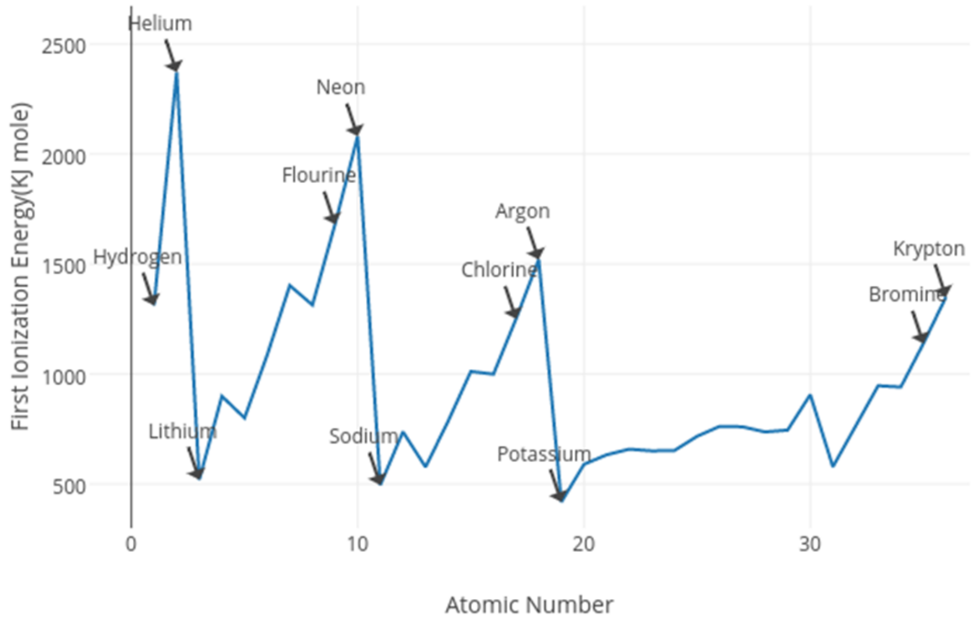


First ionisation energy is the minimum energy needed for one mole of the outermost electrons to be removed from one mole of atoms in a gaseous state.

It takes more energy to remove an electron as you go across the period. This is because the number of protons increase across the period so the positive charge on the nucleus increases. This means that the force of attraction pulling on the outer electron increases. However, you can see there is not a steady increase in first ionisation energy. There is a pattern in the dips and increases for each period.

Periodicity – the repeating pattern seen by the elements in the periodic table.

First ionisation energy – the energy needed for one mole of electrons to be removed from one gaseous atoms.

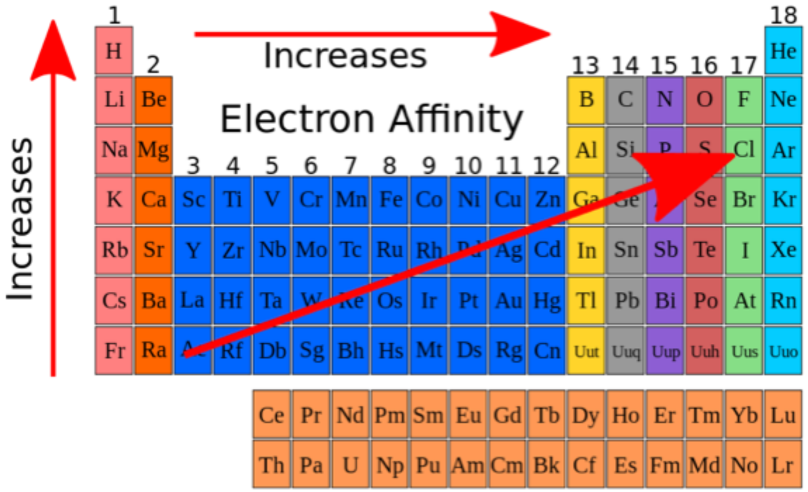
Electron affinity – the charge in energy when one mole of a gaseous atom gains one mole of electrons to form a negative ion.

Q:

Period 3 elements bond with oxygen to form oxides. The type of bonding in these oxides depends on the electronegativity of each element in the oxide. The table shows the electronegativity of some period 3 elements, as well as for oxygen. Explain how bonding in the oxides of elements in period 3 changes across the period.

element	electronegativity of element
magnesium	1.31
silicon	1.90
sulfur	2.58
oxygen	3.44

Electron affinity can be simply defined as an atom's ability to gain an electron and become a negative ion. It is the change in energy (kJ mol–1) of a neutral gaseous atom when an electron is added to the atom to form a negative ion.



Periodic Trend: Electron Affinity

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C PHYSICAL PROPERTIES OF ELEMENTS (IV)

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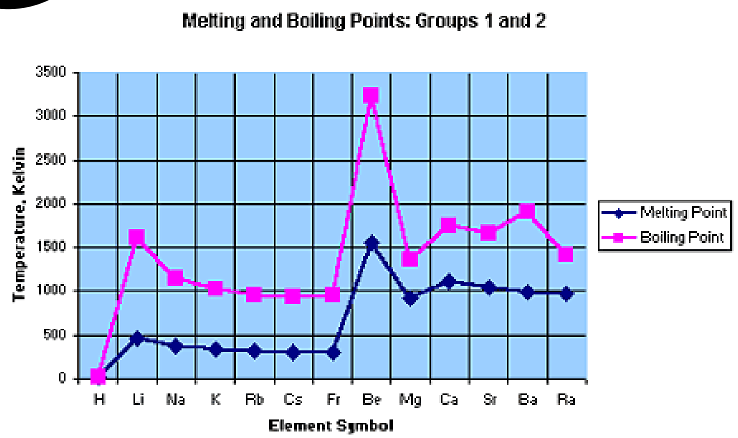


The elements in the periodic table also show periodicity for **melting and boiling points**. Melting and boiling points depend on the strength of the forces between the atoms in an element.

- Going down group 1, the melting and boiling points decrease. This means that the forces of attraction get weaker.
- The melting and boiling points increase as you go down group 7. This means that the forces of attraction get stronger.
- When an element melts, energy is used to overcome some of the attractive forces holding the atoms or molecules of the element together.
- When an element boils, most of the rest of the attractive forces are broken.
- The stronger the forces between the atoms, the higher the melting and boiling point will be.

Malleable – can be hammered into shape with breaking.
Ductile – can be hammered than or stretched into wires without breaking.

Metallic bonding allows for electrical conductivity through a solid or liquid metal. The **delocalised electrons** carry the electric charge.
The delocalised electrons in metals also absorb heat energy which gives them kinetic energy. This energy is then transferred through the metal by these electrons. Metals are good thermal conductors.


Copper

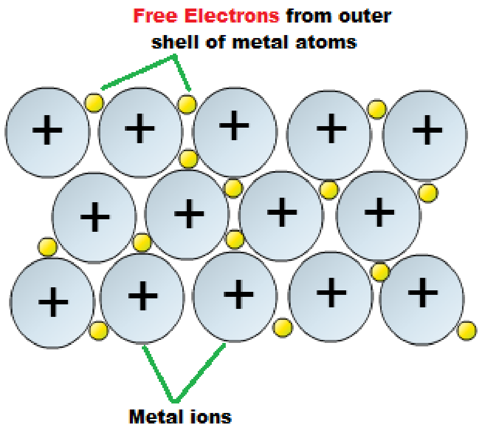

Lead


Tin


Nickel


Steel


Zinc



The structure of metals also explains why they can be **malleable** or **ductile**. The atoms in the layers are able to roll over each over. They can move to new positions without breaking the metallic bonds.

top tip

Evaluate how type of bonding, intermolecular forces and molecule size affects the melting point in elements in period 3 and groups 2 and 6.

Q:

Most metals have high melting and boiling points. The table shows the melting and boiling points of three metals: sodium, magnesium and potassium.

1. Discuss the different melting and boiling points of the three metals and the trends they show.

Metal	Group	Melting points/°C	Boiling points/°C
Sodium	1	97.72	883
Magnesium	2	650	1090
Potassium	1	63.38	759

C

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C CHEMICAL PROPERTIES OF ELEMENTS (I)

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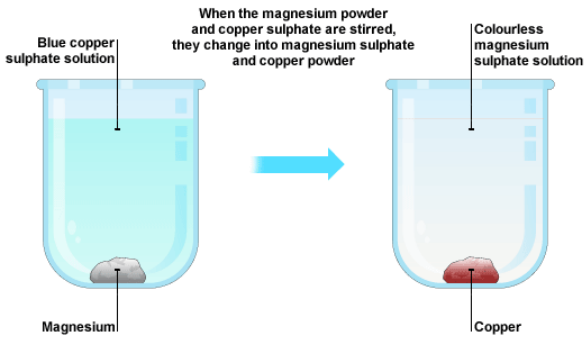
	Oxygen	Water	Dilute Hydrochloric Acid	Dilute Sulfuric Acid
Group 1	react rapidly with oxygen	react with water and produce a basic solution $2M(s) + 2H_2O(l) \rightarrow 2M^{+}(aq) + 2OH^{-}(aq) + H_2(g)$	Metals above copper in the reactivity series can react with dilute acids to form metal salts $Mg + 2HCl \rightarrow MgCl_2 + H_2$	
Group 2	burn in oxygen or air to form metal oxides $2M + O_2 \rightarrow 2MO$	produce hydroxides in the reaction with water $M(s) + 2H_2O(l) \rightarrow M(OH)_2(aq) + H_2(g)$	$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$	
Group 3	react with oxygen $4M + 3O_2 \rightarrow 2M_2O_3$	not very reactive with water	$Na + 2HCl \rightarrow 2NaCl + H_2$	

KEYWORDS

Oxidation – loss of electrons from an atom/ion.
Basic solution – a solution with a pH above 7.
Allotropes – two or more different physical forms that an element can exist in e.g. graphite and diamond are allotropes of carbon.
Amphoteric – substance that can act as both an acid and a base.

The **reactivity series** is a list of metals in order of how reactive they are with oxygen, acids and water.

- The higher a metal is in the series, the more reactive it is.
- This is because it has a higher tendency to lose an electron and form a complete outer shell.
- The more reactive a metal is, the more difficult it is to extract from its ore and the more likely it is to be found in a compound.



A metal will displace a less reactive metal in a metal salt solution.

potassium	most reactive	K
sodium		Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold		Au
platinum	least reactive	Pt

Q:

Industrial chemists have to understand the chemistry of oxides. For example, silicon dioxide is used in glass making and carbon monoxide is used in the extraction of iron from iron ore.

1. Explain how burning carbon in air can lead to the formation of carbon monoxide.
2. Write the balanced equation for the reaction between silicon and oxygen.

C MY NOTES/EXAM PRACTICE

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C CHEMICAL PROPERTIES OF ELEMENTS (II)

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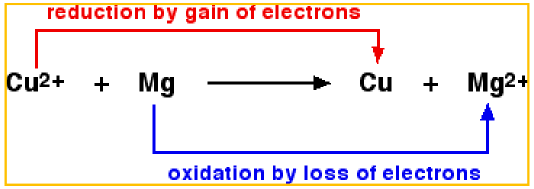

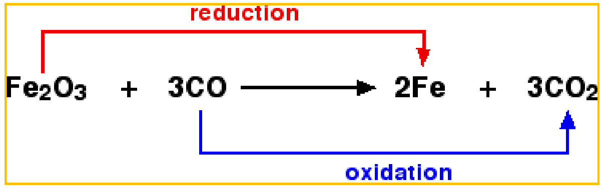

An atom becomes an ion when it loses or gains an electron or electrons. The term **redox** refers to the transfer of electrons that occurs during chemical reactions.
When atoms of an element lose electrons, it is called **oxidation**.
When electrons are gained, it is called **reduction**.

Deduce the ox state of nitrogen in HNO_3

HNO_3

+1 ↙ ↓ x ↘ 3(-2)

Sum = (+1) + x + 3(-2) = 0 (neutral compound)

+1 + x - 6 = 0

∴ x = 5 nitric(V) acid

Deduce the ox state of manganese in MnO_4^{2-}

MnO_4^{2-}

↙ x ↘ 4(-2)

Sum = x + 4(-2) = -2 (overall charge on ion = -2)

x - 8 = -2

∴ x = + 6 manganate(VI)

this is a green ion
different from the purple MnO_4^- manganate(VII)

OILRIG

Oxidation **I**s **L**oss (of electrons),
Reduction **I**s **G**ain (of electrons).

KEYWORDS

Redox – the transfer of electrons during chemical reactions.

Half equation – an equation that shows the loss or gain of electrons during a reaction

Assigning Oxidation States	
1	The oxidation state of an atom in an element is always zero. For example, in sodium, Na, it is 0 and in O_2, oxygen, it is 0.
2	The oxidation state in an element or its ion is always its charge, including for polyatomic ions
3	The oxidation state of fluorine in a compound is always −1 as it is the most electronegative element.
4	The oxidation state of oxygen is nearly always −2 (except in peroxides and FO, where it is −1, +1).
5	The oxidation state of chlorine in a compound is usually -1 unless bonded with F or O.
6	The oxidation state of hydrogen is +1 unless bonded to a metal when it is –1. Group 1 metals are +1, group 2 metals are +2, and aluminium is +3.
7	The sum of oxidation states in a compound is always 0. In polyatomic ions, the sum of the oxidation state of each element in the formula is the overall charge.

Q:

1. Work out the oxidation state of chlorine in the following compounds:

A. HCl

B. HClO

C. $NaClO_2$

D. ClO_3

E. ClO_2

F. Cl_2O_7

top tip

Practice constructing half equations, you will find several worksheets online.

C

MY NOTES/EXAM PRACTICE

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P WAVES

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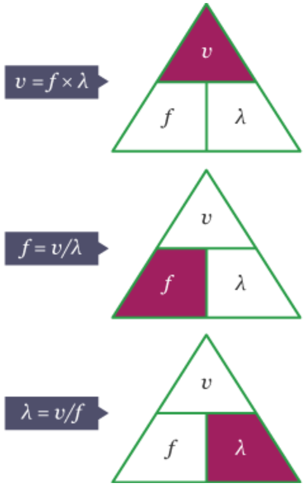
Waves generally start with a disturbance.

Waves transfer energy from one place to another, but without causing any net movement of material.

The energy transfer depends on the way an initial oscillating system is connected to its surroundings.

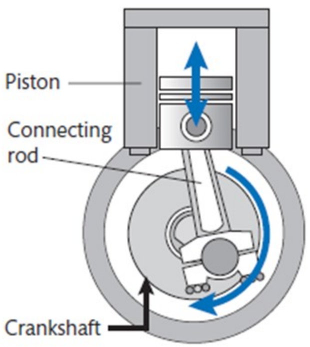
Wave Speed
V = f x λ



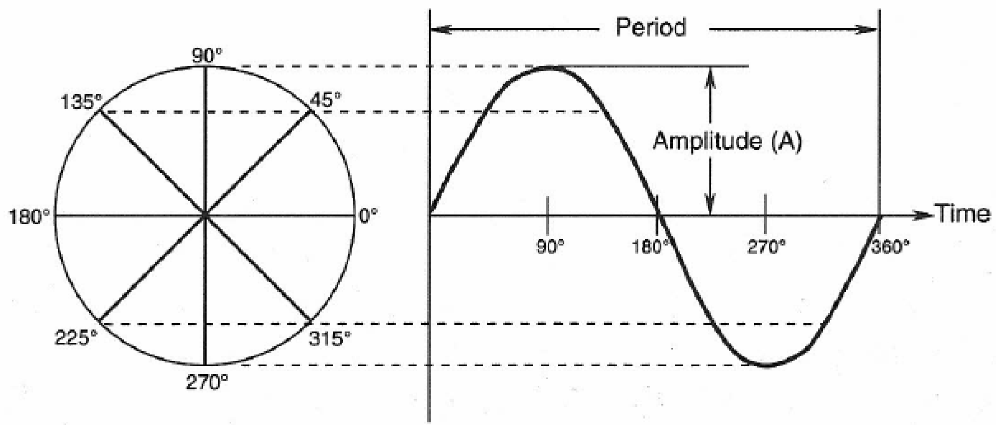
KEYWORDS

Oscillation – a regularly repeating motion about a central value.
Period (or 'periodic time') – the time taken for one whole cycle of an oscillation, i.e. before the motion starts to repeat itself. (Symbol: *T* ; SI unit: s.)
Frequency – $f = \frac{1}{T}$ i.e. the number of whole cycles occurring in one second. (Symbol: *f* ; SI unit: Hertz, Hz.)
Displacement – how far the quantity that is in oscillation has moved from its mean (rest) value at any given time.
Amplitude – the maximum value of displacement in the oscillation cycle – always measured from the mean (rest) position.

- A wave travels one wavelength during its periodic time.
- So that means you can calculate its speed, *v*, as wavelength, λ, divided by periodic time, *T*. However, instead of the periodic time, frequency is more commonly used, *f*, where $f = \frac{1}{T}$
- Frequency is measured in cycles per second or Hertz (Hz)



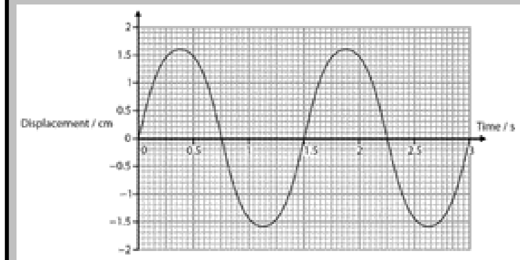
- The mathematics of oscillation and of circular motion are closely connected.
- The sine is a mathematical function of the angle through which you can imagine a crankshaft turning to drive the motion.
- You can use this idea of the angle generating a cycle of oscillation when you compare two wave motions that are not in phase with one another. The **phase difference** is usually given as an angle, where 360° (or 2π radians) equates to a whole cycle – a shift equivalent to one wavelength in distance or one period in time.



top tip

Recap the basic structure of a wave including wavelength, amplitude and frequency.

Q:



1. Give the amplitude of the wave.
2. Give the wavelength of the wave.
3. Calculate the frequency of the wave.

P

MY NOTES/EXAM PRACTICE

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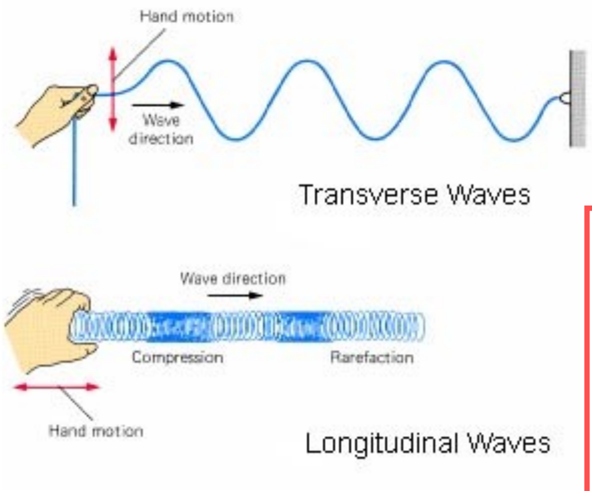
UNSURE ☐

WEAK ☐

TRANSVERSE AND LONGITUDINAL

SECURE ☐
UNSURE ☐
WEAK ☐

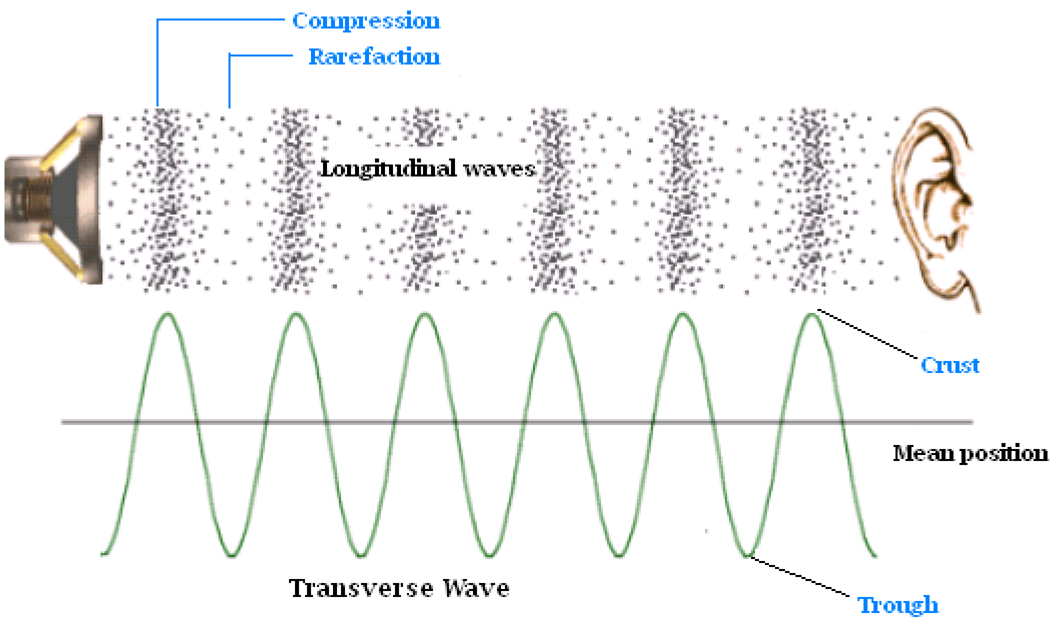


- When the displacement occurs in the same direction that the wave travels, for example in a sound wave, it is a longitudinal wave.
- In a transverse wave the displacement is at right angles to the direction of propagation of the wave, for example, water ripples and electromagnetic waves.
- In a longitudinal wave, the different displacements of particles along the direction in which the wave is propagating, lead to a series of compressions (where particles are packed closer together) and rarefactions (where they are further apart).

MY NOTES:

Earthquakes and other seismic events below the earth's surface generate two types of shock wave: a longitudinal 'pressure' wave and a transverse 'shaking' wave. They travel at different speeds and so will each arrive at different times, making earthquakes quite complex events to study.

Transmission of sound as a longitudinal wave in air



Q:

1. Explain in detail how our ears can detect sound waves. Include the terms compression and rarefaction in your answer.

top tip

Recap examples of transverse and longitudinal waves.

P

MY NOTES/EXAM PRACTICE

SECURE ☐

UNSURE ☐

WEAK ☐

P DIFFRACTION GRATINGS (I)

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Diffraction is a key characteristic of all waves. It means the tendency of a wave to spread out in all directions, transferring energy to its surroundings as it does so.

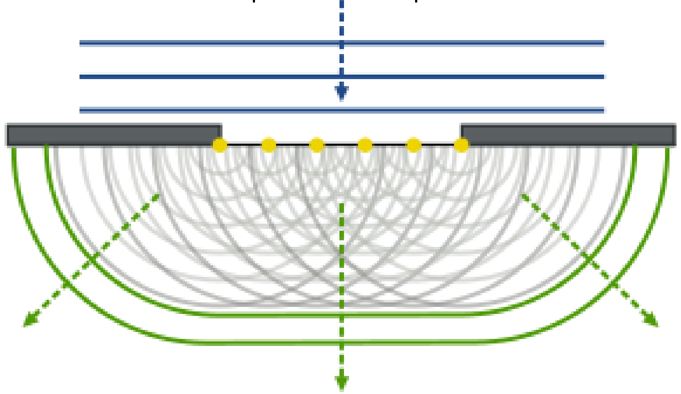
- If the advancing wave-fronts encounter a flat obstacle in front of them, like a wall, most of the wave's energy is either absorbed or reflected by the wall.
- If the obstacle has edges or gaps, wave energy can travel round the edges or through the gaps. It is then that you may notice diffraction occurring.
- Although after going through a gap much of the wave energy does keep moving forwards, some of it spreads out in other directions.

A **diffraction grating** is a flat plane object. It has a series of regular lines formed on it that block parts of an advancing wave-front.

- When a wave-front meets a diffraction grating, some of the wave's energy continues propagating forward through the gaps between the grating lines. This is **transmission**.
- Some more of the wave's energy may be absorbed in the grating itself, but the remainder of the energy is scattered backwards as a **reflection**.

MY NOTES:

The Dutch mathematician and scientist, Christiaan Huygens, developed a geometrical construction to predict the shape of waves in water.



KEYWORDS

Superposition – is the adding together of wave displacements that occurs when waves from two or more separate sources overlap at any given location in space. The displacements simply add mathematically.

Path difference – is the difference in length between two (straight line) rays, e.g. one from a particular grating gap to a given point in space and the ray from the next-door grating gap to the same point.

Interference pattern – a stationary pattern that can result from the superposition of waves travelling in different directions, provided they are **coherent**.

Coherent – literally means 'sticking together' and is used to describe waves whose superposition gives a visible **interference pattern**. To be coherent, waves must share the same frequency and same wavelength and have a constant phase difference.

Q:

1. Explain how the diffraction grating produces an emission spectrum. You can use a labelled diagram to help your explanation

P

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P DIFFRACTION GRATINGS (II)

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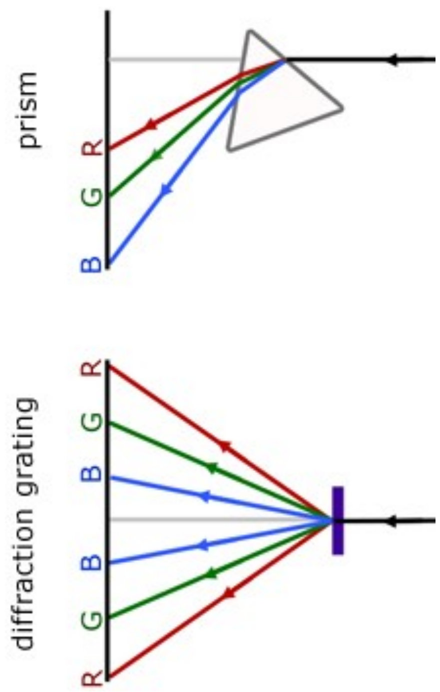
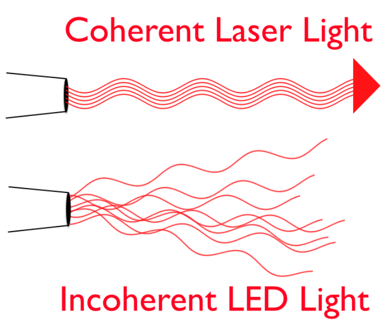
Gratings in Reflection mode

- In reflection mode, instead of looking at what comes through a grating, you look at the part of the wave energy that is bounced back off the grating surface.
- Once again, because the grating lines are regularly spaced, an interference pattern is produced.



Coherent Light Sources

- When light is emitted from or absorbed by matter, you can only explain what happens by thinking of light as being composed of tiny particles or 'packets of energy', which are called **photons**.
- When thinking about the **coherence** of light, you have to combine ideas from wave theory with the idea of individual photon particles – what is called 'wave-particle duality'.



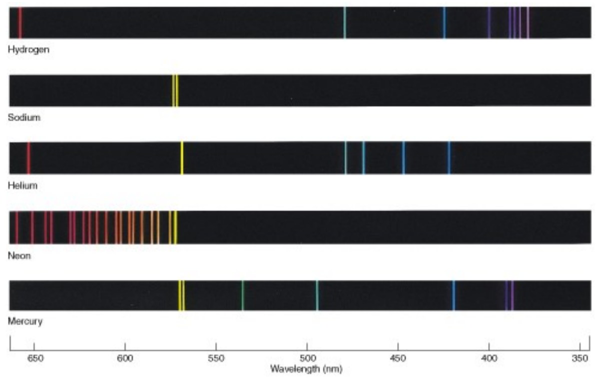
Emission Spectra

- The quantum theory of light and other electromagnetic radiations is based on the experimental observation that there is a simple relationship between the frequency, f, of the radiation and the energy, E, carried by each photon:

$$E = hf$$

where h is the Planck constant, −6.626 070 . 10^{-34} Js. That constant of proportionality between energy and frequency has been very precisely measured and experiments indicate it is universal.

- If a chemical element or compound is vaporised by heating in a flame, or if you pass an electric current at high voltage through a gas, you typically see light emitted of a characteristic colour, according to the chemical nature of the material you are testing. When you look at the spectrum of that light, by splitting it up using a prism or a diffraction grating, what you see is a number of bright, coloured lines at definite frequencies. This is an **emission spectrum**. Each line in the spectrum matches to photons all emitted with very nearly the same frequency – and therefore they also each have virtually the same energy.



An Emission Spectra

Q:

1. Light from a sodium-vapour lamp passes through the slits in a diffraction grating and creates a pattern on a screen. This pattern is called an emission spectrum. Which property of light produces the pattern on the screen?

A absorption

B interference

C reflection

D refraction

2. Describe what is meant by coherence.

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P STATIONARY WAVES RESONANCE

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In a **stationary wave** (or standing wave) energy is stored rather than transferred to other locations.

- Oscillations of different amplitudes occur along the length of the wave in a pattern that does not change over time.
- Points of minimum (ideally zero) amplitude are called **nodes** and occur at every half-wavelength along the wave's extent.
- Intermediate between the nodes are **antinodes** – points of maximum amplitude.

Resonance – the storing of energy in an oscillation or a stationary wave, the energy coming from an external source of appropriate frequency.

- Stationary wave patterns most often occur in resonators, where the wave motion is confined in a fixed space. The resonator has boundaries that prevent the wave progressing further and reflect its energy back.
- The resonator will also have a mechanism for interacting with and absorbing travelling wave energy from outside itself. Small amounts of energy collected over a period of time can be stored up in the stationary wave and build up a much larger amplitude oscillation.
- This effect is **resonance**. It happens when the wave energy coming in from outside has a **forcing frequency** equal or very close to a **natural frequency** of the resonator.

Musical Instruments

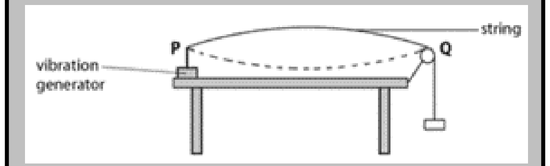
Both stringed and wind instruments depend on resonance to produce their musical notes.
In a stretched string, the oscillations are transverse, and the speed, *v*, at which waves travel down its length, *L*, depend on the string tension, *T*, and on the string's mass, *m*, per unit length, μ (= $\frac{m}{L}$).

The wave speed can be calculated using the formula: $v = \sqrt{\frac{T}{\mu}}$

Q:

When a string on a guitar is plucked a stationary wave is set up and a sound is produced. The diagram shows how a stationary wave on a stretched string might be studied.

1. On the diagram, label a node and an antinode.



2. State the relationship between the distance **PQ** and the wavelength of the wave.

top tip

Explain why stationary waves are seen only at certain frequencies.

Applications of Stationary Waves
Radio and TV antennas have a reflector element that bounces the incoming waves back and creates a stationary wave pattern. The detector is placed at an antinode position for the particular wavelength of radiation the aerial has been designed to pick up.
In **microwave ovens**, stationary wave patterns caused by reflections for the metal sides of the oven with hot and cold spots corresponding to antinodes and nodes.
Bound electrons in atoms and molecules behave like stationary waves bouncing around in the space they are restricted to by the attraction of the nuclear positive charge. The discrete energy levels that electrons can occupy each correspond to a stationary wave pattern. Wave patterns with higher numbers of nodes correspond to higher energy levels.

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P PRINCIPLES OF FIBRE OPTICS

Light (or electromagnetic radiation of other frequencies) travels best through a vacuum. Its rapidly oscillating electric field generates an oscillating magnetic field, and the changing magnetic field in turn generates another nearby oscillating electric field. And so the wave progresses rapidly through space.

- When the waves have to travel through matter, their progress is impeded by the electronic charges in the atoms and molecules. Metals, which are full of freely moving electrons, just stop the wave oscillation completely.
- Many other materials absorb some or all of the light and so look coloured or even black.
- In transparent materials, like water, glass and many plastics, the waves are not stopped or absorbed, but they are slowed down. The ratio of the speed of light in vacuum, *c*, to its speed in the material medium, *v*, is called the **refractive index**, *n*, of the medium.

Refractive index = $n = \frac{c}{v}$

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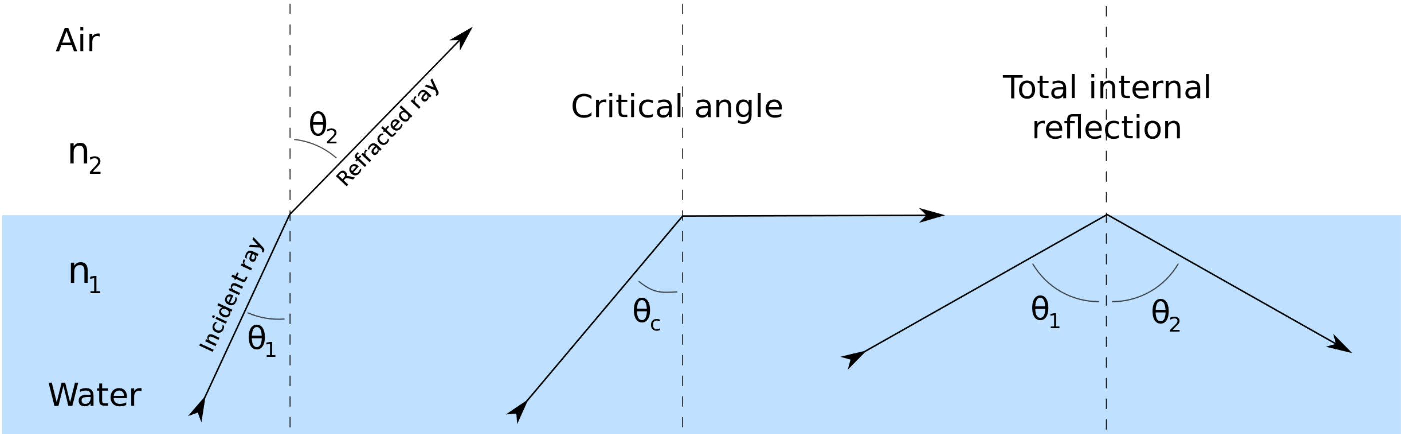

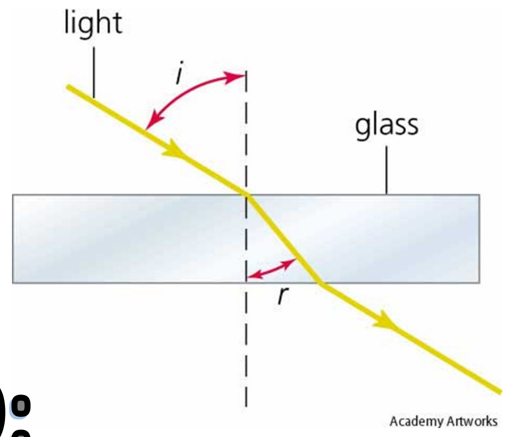

Critical Angle: When light passes from one medium (material) to another it changes speed. This is because the speed of a wave is determined by the medium through which it is passing.
When light speeds up as it passes from one material to another, the angle of refraction is bigger than the angle of incidence. For example, this happens when light passes from water to air or from glass to water.

When the angle of refraction is equal to 90°, the angle of incidence is called the critical angle, θ_c
At any angle of incidence greater than the critical angle, the light cannot pass through the surface - it is all reflected.
This is called **total internal reflection**.
Total because all of the energy is reflected.
Internal because the energy stays inside the material.
Reflection because the light is reflected.

The relationship between critical angle and refractive index is $\sin\theta_c = \frac{1}{n}$

Q:

A fibre optic cable is made from a material that has a critical angle of 43.8 °.

1. Calculate the refractive index for this material.

top tip

Make sure you can use the equations on this page to calculate refractive index and critical angle.

P

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P OPTICAL FIBRES (I)

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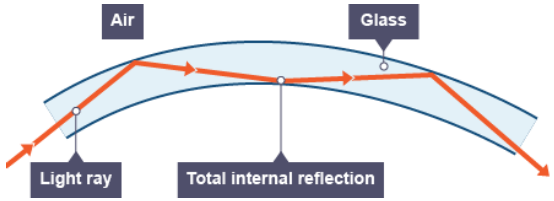
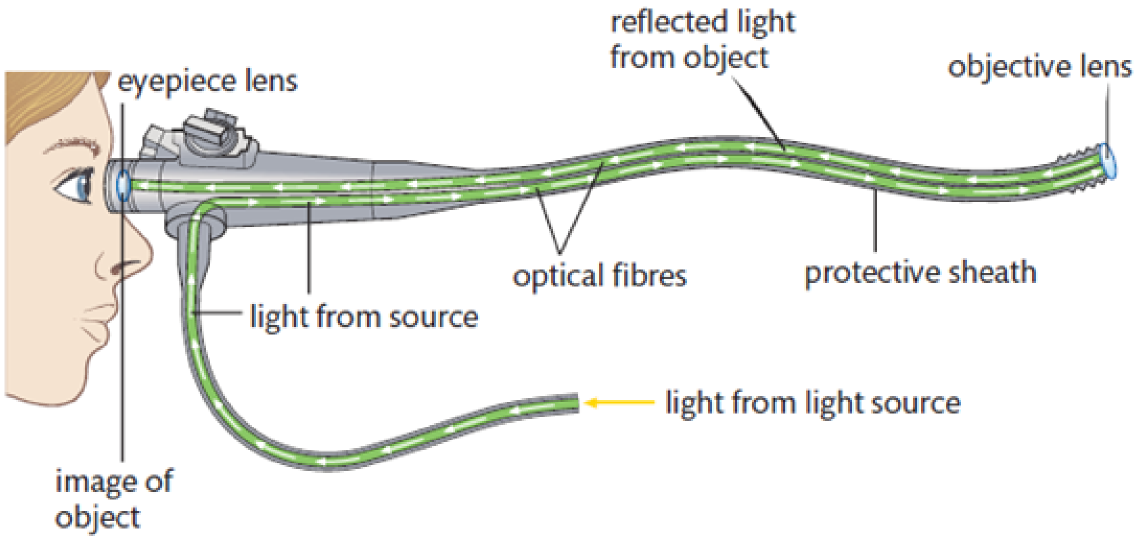
Optical fibres are very long thin cylinders of glass or, sometimes, plastic. Light is fed into the cut end of the fibre, so when it hits the sides of the fibre, it almost always does so at angles greater than the critical angle. That means all the rays of light get totally internally reflected and keep bouncing down the length of the fibre.

- No wave energy gets lost through the walls of the fibre, although as glass is not perfectly transparent, some is gradually absorbed.
- This makes light in optical fibres a much more efficient way of transmitting signals than sending electrical pulses down copper cables. Copper cables suffer from quite large losses due to electrical resistance, meaning that after a few hundred metres most of the signal has been attenuated away and amplifiers are needed to boost it up again.

Fibre Optics in Medicine	
• Endoscopes are optical instruments with long tubes that can be inserted into a body organ through an opening such as the throat, nose, ear canals or anus. • These allow a trained medical practitioner to see inside a body organ, for example, the upper oesophagus and stomach or the colon and intestines, without undertaking surgery. • Endoscopes are also used during keyhole surgery to guide the use of surgical instruments with remote handling, which are often incorporated into the same tube system.	Each fibre in the bundle is as thin as a human hair and consists of: • a core • cladding • protective plastic buffer coating The image transmitted is pixelated (i.e. formed of coloured dots), since each fibre only transmits one pixel of coloured light. So the resolution of the image depends on the number of fibres in the bundle.





top tip

Make sure you can clearly explain how an endoscope works.

Q:

1. Give **one** use of fibre optics in medicine.
2. Explain why there is total internal reflection in an optical fibre.
3. A technician who is using the endoscope accidentally bends the optical fibres to a very sharp angle. The optical fibres do not crack or break. He notices that the brightness of the light leaving the optical fibres is reduced. Explain why the brightness of the light is reduced.

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P OPTICAL FIBRES (II)

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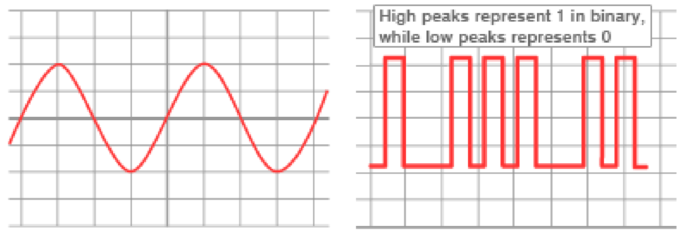
Analogue Signals	Digital Signals
• the electrical signals made by a microphone, which mimic the shape and intensity of the sound waves they are detecting • the position of the pointer on a pressure dial gauge • the waveform displayed on a cathode ray oscilloscope, which copies and shows the variation of an AC voltage with time.	• Digitising information not only makes it possible to send more data faster than using analogue transmission. It also makes the transmission much more reliable and interference free. • Converting a signal from analogue to digital is carried out electronically using an analogue to digital (A to D) converter.

KEYWORDS

Analogue signal – a signal whose strength is proportional to the quantity it is representing.
Digital signal – conveys in binary code a number that represents the size of the measured quantity.

Analogue signal Digital signal



Analogue signals work by transmitting sounds and pictures as continously varying waves.

Digital information is sent as computerised pulses of information, coded as 1s and 0s.

Fibre optic broadband networks
Broadband is used as a relative term to indicate the speed and carrying capacity of a data channel.
In connection with the internet it has been used to market the improvement from earlier telephone dial up connections, which were very limited and slow. Fibre optic broadband has been progressively replacing copper cable connections with consequent gains in data speed.

Multimode fibre is the standard fibre cable used for sending optical signals over short to medium distances – for example, connections to instruments, jumpers in cabinets, small local area networks

Single mode fibre has an even narrower core (8 µm to10 µm), which is less than ten wavelengths of the infra-red light that is used in them. This means there is just no space for different beams travelling at different angles down the core. Instead, the light wave moves as a single wave-front straight down the centre of the fibre, and all the signal energy reaches the far end of the fibre at the same instant. Millions of kilometres of this high quality cable is laid every year to build the fibre optic networks for telephone, cable TV and broadband internet communications.

Q:

1. The refractive index of the optical fibre is 1.48 The speed of light in air is approximately $3\text{x}10^{8}$ m/s Calculate the speed of light in the optical fibre.

2. Optical fibres use digital signals for communication. Digital signals are clear and of high quality. They can carry a lot of data. Explain **one other** advantage of using digital signals in long distance communication.

top tip

Recap the properties of analogue and digital signals from GCSE.

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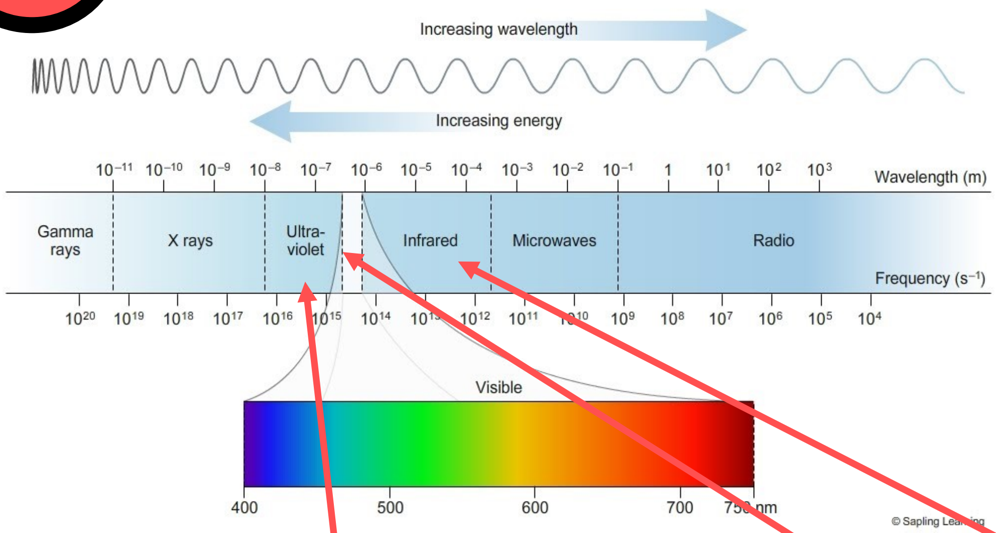
P ELECTROMAGNETIC WAVES



There are frequencies just above your visible range that can be seen by bees and some other animals, which help plants grow and which cause sunburn. These are ultra-violet light (UV), because the frequencies are above those of violet

Your eyes can only detect a very small range of frequencies. These are visible light.

You can sense frequencies just a little lower than that of red light as radiant heat warming you. These are infra-red radiation (IR).

The remaining types of radiation are named according to how they are produced. At the highest frequencies the frequency ranges for X-rays and for *γ*-rays (gamma rays) overlap somewhat. X-rays are produced by high energy atomic electron transitions and are just a higher energy version of light and UV radiation. On the other hand, *γ*-rays come from nuclear disintegrations and from collisions between high energy sub-atomic particles.

Speed of electromagnetic waves in a vacuum

Light, and all forms of electromagnetic radiation, travel at the same speed through vacuum: 2.997 925x10^8 ms^{-1}. This is a physical constant value that is usually denoted by the letter, *c*.

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Inverse square law for intensity of a wave

Waves transfer energy, and energy is a quantity that is always conserved. Wave-fronts propagating out from a point or a spherical source will themselves be spherical.

As each wave-front increases in radius it also increases in area. The formula for the surface area of a sphere of radius *r* is 4π*r*2. The energy in the moving wave-front is distributed over that expanding area, and so its intensity decreases accordingly:

$$I = \frac{k}{r2}$$

where *I* is intensity of wave, *k* is a constant and *r* is distance from source.

top tip

Review page 82 of the textbook for applications of EM waves.

Applications of EM Spectrum:

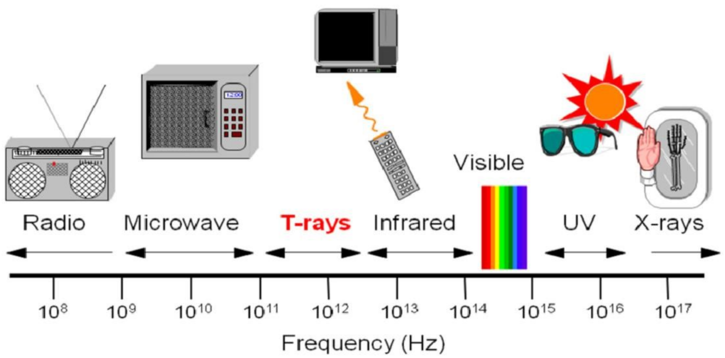
Satellite communication

Mobile phones

Bluetooth

Wifi

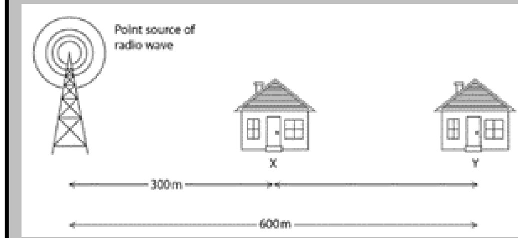
Infrared



Q:

1. Compare the use of mobile phones, Bluetooth® and Wi-Fi in communications.

Your answer should include reference to their uses, frequencies and range.



2. Determine how the intensity at Y, *IY* , compares with the intensity at X, *IX* .

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Sample Exam Papers

EXAM DATE:

Monday 5th June 2016,
9:00am, 1h 30m

Now that you have completed your revision it is time to try some sample exam questions. Attached with this booklet you will find two sample exam papers from BTEC. Spend 1 hour 30 minutes on each paper. Good luck!