Science Knowledge Organisers

Year 11 PC2 (December Exams)

Biology Paper 1

Chemistry Paper 2

Physics Paper 1

Kettering science Academy

What is a 'knowledge organiser'?

A knowledge organiser is simply a collection of the all of the information which your teacher would like you to be able to **recall** from a particular topic. That means that it **does not have everything on it** for a unit of study but it does have **the most essential things to learn.**

A knowledge organiser has lots of facts and definitions on it. Did you know that there is as many new words in studying science as there is in studying a language?

A knowledge organiser does **not develop skills**, so good revision will involve **lots of practice questions** as well as learning the content of these organisers.

What do I do with it?

For most of us, the first thing that we learned at school in reception was our phonics sounds. We learned them by repetition – seeing them again and again until the association between the sound and the image stuck. We need to do the same thing with these knowledge organisers!

Your teacher will probably be using knowledge organisers as you are taught. They will be referred to in class and you should have regular small tests on what you have learned.

Our knowledge organisers are deliberately broken into small lesson sized chunks for you to learn. Typically a teacher may ask you to 'learn box 2 and 3' for a homework.

By the time you come to an assessment – an exam or test – you should already be familiar with the knowledge organisers and already know some of it. They can then be relearned as a part of the revision and assessment preparation procedure.

Retrieval Practice

A key part of learning anything is the act of trying to remember. In class, your teacher will be helping you to do this by asking lots of questions and setting quizzes. **The more often you try to remember something the more likely you are to remember it**. With knowledge organisers you can achieve the same thing at home.

Why are we doing this?

Research has shown that **the more you know** the **more you can learn.** By being able to recall the facts, you are able to understand more complicated ideas because you **already know what the key words mean.** You will also already have a set of ideas in your mind that the new ideas can connect to (this is often referred to as a **schema**).

What are the best techniques for memorising using a knowledge organiser?

READ COVER WRITE

Make sure you are working somewhere quiet and that you have something to write with and some paper. Focus on learning on part of the knowledge organiser only, for example box one. Read through it carefully several times. When you think you've got it, cover over the knowledge organiser and write it all down. Then check what you've been able to remember. Read the bits that you could not recall, cover and write again.

TEST ME

Once you have learned the sections, its time to see if you can remember larger amounts.

Ask a friend or family member to test you on the content of the knowledge organiser page. They don't need to be experts – only to say whether you have remembered it correctly.

TEST EACH OTHER

If you are revising with class mates, testing each other is great. By doing this you are thinking about what you need to know when you are answering questions but also when you are checking to see if your class mate is right. This works well on video calls!

MAKING FLASH CARDS

Some students find making flash cards really helps. You are thinking about what needs to be learned as you write! But don't fall into the trap of writing them and never using them! Once written they should be used regularly – you can test yourself with them or test each other!

Spaced Learning

All of the techniques work best when they are done **little and often**. Aim to repeat something you have learned a week – studies have shown that once you learn something, if you see it again after a week recall is better long term. Then again after a month… and so on.

Application

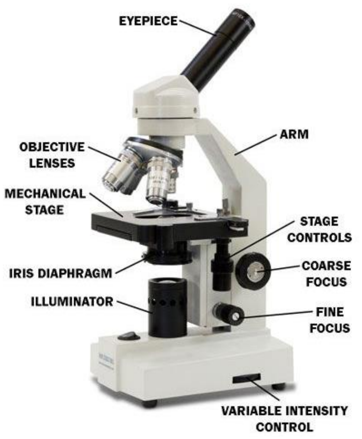
Once you have memorised some of the information, or have made a good start, it's a good idea to start trying to **use that knowledge**. Websites like **Seneca** and **Educake** provide great banks of questions for this.

B1: Biology key concepts

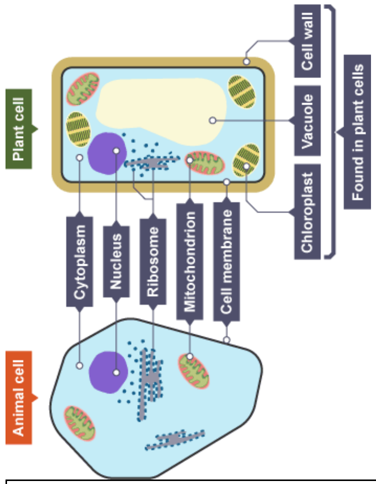
Lesson sequence

1. Microscopes
2. Plant and animal cells
3. Measuring cells
4. Core practical: using microscopes
5. Specialised cells
6. Bacterial cells
7. Digestive enzymes
8. How enzymes work
9. Factors affecting enzymes
10. Core practical: enzymes and pH
11. Cell transport
12. Core practical: osmosis in potatoes

1. Microscopes	
***Magnification**	The number of times bigger something appears under a microscope.
***Eyepiece lens**	The lens on a microscope that you look through.
***Objective lens**	The lens at the bottom of a microscope. There are normally three you can choose from.
***Total magnification**	Eyepiece lens x objective lens.
****Resolution**	The smallest distance between two points so that they can still be seen as two separate points.
****Stains**	Dyes added to microscope slides to show the details more clearly.
****Milli**	Thousandth, $1x10^{-3}$ (a millimetre is a thousandth of a metre).
****Micro**	Millionth, $1x10^{-6}$ (a micrometre is a millionth of a metre).
****Nano**	Billionth, $1x10^{-9}$ (a nanometre is a billionth of a metre).
****Pico**	Trillionth, $1x10^{-12}$ (a picometre is a trillionth of a metre).



2. Plant and animal cells	
***Cell**	The basic structural unit of all living things (the building blocks of life).
***Parts of an animal cell**	Cell membrane, cytoplasm, nucleus, ribosomes, mitochondria.
***Parts of a plant cell**	Cell membrane, cytoplasm, nucleus, ribosomes, mitochondria, cell wall, permanent vacuole, chloroplasts.
***Cell membrane**	Controls what enters and leaves the cell.
***Cytoplasm**	A jelly-like substance where chemical reactions take place.
***Nucleus**	Contains DNA and controls the cell.
***Ribosome**	Produces proteins.
***Mitochondria**	Releases energy by aerobic respiration.
***Cell wall**	Protects and supports the cell, made of cellulose.
***Permanent vacuole**	Stores sap and helps to support the cell.
***Chloroplast**	Where photosynthesis happens, contains chlorophyll.



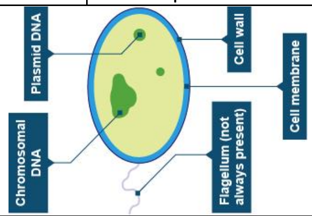
3. Measuring cells	
***Micrograph**	A picture produced by a microscope.
***Light microscope**	A microscope that uses light, can magnify up to 1500 times.
****Electron microscope**	A microscope that uses electrons to produce an image, can magnify up to 1,000,000 times.
****Actual size of a cell**	Actual size = measured size / magnification
****Convert mm to µm**	Micrometres (µm) = millimetres (mm) x 1000

4. Core practical – using microscopes (CP1)	
***CP1 – key question**	What do cells look like under a light microscope?
***CP1 – Prepare the slide**	Collect the cells you are studying and place them on the slide. Add a drop of stain and cover with a cover slip.
***CP1 – Select lens**	Choose between the 4x, 10x and 40x objective lenses.
***CP1 – Place slide in microscope**	Place slide on microscope stage, adjust the coarse focus until the lens is just touching the slide.
***CP1 – Rough focus**	Looking through the eyepiece, slowly adjust the coarse focus until you see a rough image.
***CP1 – Fine focus**	Looking through the eyepiece, slowly adjust the fine focus until you see a sharply focussed image.
***CP1 – Record the image**	Draw what you see, label any cell parts you can recognise and repeat with different objective lenses.
***CP1 - Results**	As you increase the magnification of the objective lens, the cells appear larger and more detailed.

5. Specialised cells	
****Small intestine cell**	**Job:** To absorb small food molecules produced during digestion. **Adaptations:** Tiny folds called microvilli that increase their surface area.
****Sperm cell**	**Job:** Fertilise an egg and deliver male DNA. **Adaptations:** A tail to swim, mitochondria to give energy for swimming, an acrosome to break through the egg's jelly coat, haploid nucleus with only half the total DNA.
****Egg cell**	**Job:** To be fertilised by a sperm and then develop into an embryo. **Adaptations:** Jelly coat to protect the cell, many mitochondria and nutrients to provide energy for growth, haploid nucleus with only half the total DNA.
****Ciliated epithelial cell**	**Job:** To clear mucus out of your lungs (and other internal surfaces). **Adaptations:** Small hairs on the surface – called cilia – which wave to sweep mucus along.

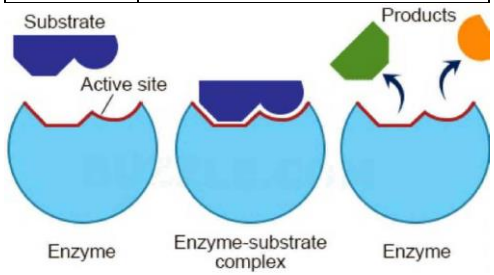
6. Bacterial cells	
***Parts of a bacterial cell**	**All bacteria:** Cell membrane, cell wall, cytoplasm, ribosomes, chromosomal DNA, plasmid DNA **Some bacteria:** flagellum.
****Chromosomal DNA**	Large piece of DNA containing most genes.

****Plasmid DNA**	Small loops of DNA containing a few genes.
****Flagellum**	A tail used for movement.
****Eukaryotic cells**	Cells with a nucleus.
****Prokaryotic cells**	Cells without a nucleus.
*****Standard form**	A way of writing numbers in terms of powers of ten. E.g. $0.015 = 1.5 \times 10^{-2}$ $0.000458 = 4.56 \times 10^{-4}$ The index of ten (the 'minus' number) tell you which decimal point to start on.



7. Digestive enzymes	
***Digestion**	Breaking large food molecules down into ones small enough to absorbed by the small intestine.
***Catalyst**	A substance that speeds up a chemical reaction without being used up.
***Enzyme**	A protein that works as a catalyst to speed up the reactions in our cells.
***Digestive enzymes**	Enzymes that break large food molecules down into smaller ones.
****Amylase**	**Where found:** saliva, small intestine **What it does:** breaks down starch into simple sugars such as maltose
****Lipase**	**Where found:** small intestine **What it does:** breaks down fats into fatty acids and glycerol
****Protease**	**Where found:** stomach (pepsin), small intestine (trypsin) **What it does:** breaks down proteins into amino acids

8. How enzymes work	
***Substrate**	The chemical(s) that an enzyme works on.
***Active site**	An area of an enzyme with the same shape as the substrate.
****Lock and key mechanism**	The substrate moves into the active site and reacts to form the products. The products leave the active site so another substrate can then enter and so on.
****Specificity**	Each enzyme can only work on one substrate because the shape of the active site has to match.
***Denature**	When the shape of the active site changes shape so the enzyme stops working.



9. Factor affecting enzymes	
***Optimum temperature**	The temperature when an enzyme works fastest (about 37^{o} for human enzymes).
****Changing the temperature**	**Increasing to optimum**: rate increases because particles move faster **Increasing past optimum:** rate decreases as enzyme denatures
***Optimum pH**	The pH when enzymes work fastest (around pH 6-8 for most human enzymes)
****Changing pH**	Rate decreases as you move away from the optimum because the enzyme denatures.
****Increasing substrate concentration**	At first the rate increases, but then it levels out as the enzyme is working as fast as possible.

10. Core practical – enzymes and pH (CP2)	
***CP2 – key question**	How does the rate that amylase works change as you change the pH?
***CP2 – Prepare your reactants**	Place starch solution, amylase solution and pH 7 buffer into separate test tubes and warm them in a water bath at 40^{o}C
***CP2 – Prepare your dropping tile**	Place a few drops of iodine solution into each well of a spotting tile.
***CP2 – Start the reaction**	Mix reactants together, start the stop watch and keep the mixture warm in the water bath.
***CP2 – Test for starch**	Remove a small amount of mixture and place in a well on the spotting tile.
***CP2 – Record your results**	Repeat the test until the mixture does not go black (no starch). Record the time.
***CP2 – Vary the pH**	Repeat with different pH buffers from pH 3 to pH 10
***CP2 – Results**	The amylase works fastest around pH 7 and more slowly at pH high or lower than this.

11. Cell transport	
***Concentration**	The number of particles in a given volume (the strength of a solution).
****Concentration gradient**	The difference in concentration between two neighbouring areas.
***Diffusion**	The movement of particles from high to low concentration (down a concentration gradient).
***Diffusion examples**	**Lungs:** oxygen into blood, carbon dioxide out of blood **Leaf:** carbon dioxide into leaf, oxygen out of leaf.
****Partially permeable membrane**	A membrane that allows some molecules but not others to pass through it (like a cell membrane).
****Osmosis**	The movement of water across a partially permeable membrane from high water/low solute conc to low water/high solute conc.
****Osmosis examples**	Water into plant roots, water in/out of any cells.
***Active transport**	Using energy to move substances from low to high concentration (up a concentration gradient).
***Active transport examples**	Minerals being absorbed into plant roots.

12. Core practical – osmosis in potatoes (CP3)	
***CP3 – Prepare potatoes**	Cut six similar pieces of potato, blot them dry and weigh them.
***CP3 – Run the experiment**	Place each potato piece in a test tube with sucrose (sugar) solutions with concentrations from 0% to 50%
***CP3 – Record results**	Blot each potato piece dry and re-weigh it.
***CP3 – Calculate percentage mass change**	% change = (final value – starting value) / starting value x 100
***CP3 – Results**	Potato in weaker sucrose solutions gain mass because water enters potatoes by osmosis, those in stronger solutions lose mass as water leaves by osmosis.

B2: Cells and Control

1. Mitosis

Cell cycle	The life of a cell comprising of interphase and mitosis.
Interphase	Preparation for mitosis in which extra cell parts are made and DNA chromosomes are replicated (copied).
Mitosis	When one cell divides into two genetically identical daughter cells.
Prophase	The membrane of the nucleus breaks down and spindle fibres start to form.
Metaphase	Spindle fibres fully form and chromosomes line up across the **m**iddle of the cell.
Anaphase	Chromosome copies get pulled **a**part and move to each end of the cell.
Telophase	A new membrane forms around each set of chromosomes to form **t**wo nuclei.
Cytokinesis	The two new cells fully separate.
Diploid	The type of cells produced by mitosis which have two sets of chromosomes (23 pairs in humans).
Asexual	Type of reproduction with just one parent producing a clone of itself through mitosis.
Cancer	When mitosis happens out of control forming large lumps of cells called tumours.

2. Animal Growth

Growth	Increase in size due to increased numbers of cells.
Percentile	A measure of the growth of a child that compares them to other children of the same age.
90th percentile	90% of children will have a mass below this percentile on a percentile growth curve.
50th percentile	Average for height/mass for the age.
Differentiation	The process by which an unspecialised cell becomes specialised.
Specialised cell	A cell with special features designed for a specific job.
Red blood cell	Specialised cell with no nucleus (more room for haemoglobin) and a large surface area (allowing for quicker diffusion).
Fat cell	Specialised cell with large fat droplets in the cytoplasm which is stored until energy is needed.
Muscle Cell	Specialised cell with contractile proteins than can shorten the cell.

3. Plant Growth

Plant growth	Cell division creates more cells, elongation makes these cells get bigger.
Meristems	Areas in the tips of roots and shoots where cell division and differentiation happens.
Xylem	Specialised cells which form a hollow tube of dead cells to allow water to pass through.
Root hair cell	Specialised cell with a large surface area to allow roots to take in more water / mineral ions.
Percentage change	% change = (final value – starting value) / starting value x 100

4. Stem Cells

Stem cell	An unspecialised cell that can undergo cell division and differentiation to form specialised cells.
Embryonic stem cell	A stem cell that can become any kind of cell. Found in developing embryos.
Adult stem cell	A stem cell that can only become limited types of cell. Found in animals after birth.
Stem cells in medicine	It is hoped they can be used to replace damaged cells in diseases like type 1 diabetes or leukaemia, or to grow new organs for transplant.
Problems with stem cells	They may potentially cause cancer, stem cells may be rejected if used in other people than where they were taken from.

5. The Nervous System

Nervous system	Organ system made up of the CNS and nerves. Allows all parts of the body to work together to gather information, make decisions and control responses.
CNS	Central nervous system- The brain and spinal cord – controls the body.
Stimulus	Anything your body is sensitive to (e.g. changes inside or outside the body).
Sense organ	Contain receptor cells that detect stimuli (e.g. eyes, ears, skin).
Neurone	A nerve cell
Impulse	Electrical message carried by a neuron.
Response	The action that the nervous system makes happen.
Sensory Neurone	Nerve cell that carries impulses from sense organs to the CNS.
Cell body	The central part of a nerve cell containing its nucleus.
Dendron and axon	The long parts of a nerve cell carrying impulses towards the cell body (dendron) and away from it (axon)
Dendrites	Branches at the beginning of a dendron that connect to receptor cells or another neuron.
Axon terminals	Branches at the end of an axon that connect to a muscle or another neuron.
Myelin sheath	A fatty layer around the axon and dendron that insulates it to prevent the impulse from losing energy and speeds the impulse up.
Voluntary Response	Stimulus detected by receptor → impulse sent along sensory neurone → brain makes decision → impulse sent along motor neurone → effector carries out response.

6. Neurotransmission Speeds

Neuro-transmission	The travelling of an impulse along a neuron and into another.
Effector	The body part that produces the response, often a muscle.
Synapse	Small gap between two neurons where the axon terminals of one meet the dendrites of another.
Neuro-transmitter	Chemicals released by axon terminals that diffuse across the synapse to trigger a new impulse the dendrite of another neuron.
Relay neuron	Nerve cell in the CNS that links sensory and motor neurones.
Motor neuron	Nerve cell that carries impulses from the CNS to effectors. Dendrites join onto cell body, long axon.
Reflexes	Automatic responses that happen very quickly without conscious thought to keep the body safe.
Reflex arc	Neurone pathway that bypasses the brain. Stimulus → receptor → sensory neurone → relay neurone → motor neurone → effector

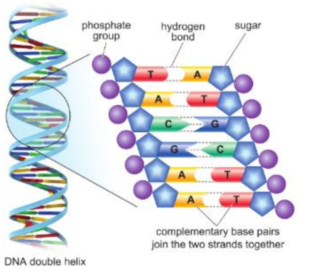
Lesson	Memorised?
1. Mitosis	
2. Animal Growth	
3. Plant Growth	
4. Stem Cells	
5. The Nervous System	
6. Neurotransmission Speeds	

B3: Genetics

1. Meiosis

Gametes	Sex cells- egg and sperm
Fertilisation	Sperm cell fuses with egg cell and nuclei combine.
Zygote	A fertilised egg cell
Gene	Length of DNA coding for a protein. Controls your characteristics
Genome	All the DNA and genes in an organism
Diploid	A cell that has 2 sets of chromosomes- 23 pairs of chromosomes in humans
Haploid	A cell with 1 set of chromosomes- 23 single chromosomes in humans
Meiosis	Cell division that makes gametes
Stages of Meiosis	DNA replicates, cell divides into 2 diploid cells, these divide into 4 haploid daughters.
Meiosis Daughter Cells	One division by meiosis creates 4, haploid, non-identical daughter cells.

2. DNA

Chromosome	Large DNA molecule made into a small package by tightly coiling DNA around a protein.
DNA Structure	Two strands, double helix, complementary base pairs, sugar-phosphate backbone 

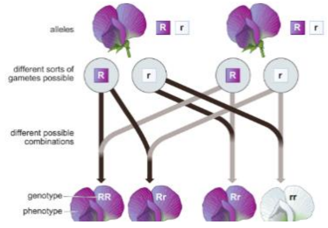
DNA Bases	Adenine, A; thymine, T; cytosine, C; guanine, G
Complementary Base Pairs	A pairs with T C pairs with G
Hydrogen Bonds	Weak force holding the two strands of DNA together. C and G form 3 bonds A and T form 2 bonds
DNA Analysis	Uses small differences in DNA to determine family relationships or link people to crimes.

3. DNA Extraction Method

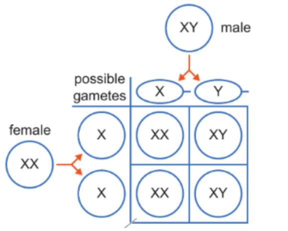
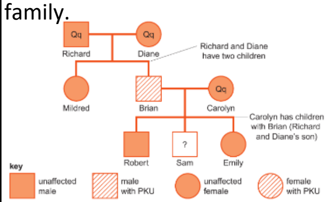
Mix water, salt and detergent	Salt makes DNA clump together, detergent breaks down cell membranes to release DNA.
Mash fruit/veg and add solution	Mash to increase the surface area.
Leave in water bath at 60°c	Heat makes it react quicker.
Filter the mixture and collect filtrate	Removes unwanted lumps.
Measure out 10cm³ of filtrate and add two drops of protease	Protease breaks down proteins around the DNA
Gently add ice cold ethanol	DNA is insoluble in ethanol so precipitates.
Leave for several minutes	So a white DNA layer forms.

4. Alleles

Allele	Different version of the same gene. We have two alleles of each gene.
Homozygous	Two copies of the same allele
Heterozygous	Two different copies of an allele
Dominant Allele	One copy needed for characteristic to show. Written as a capital.
Recessive Allele	Two copies for the characteristic to show. Written as lowercase.
Genotype	The combination of alleles in an organism.

Phenotype	The characteristics produced by the alleles.
Genetic Diagram	Shows the likelihood of offspring produced by parents with certain genotypes. 

5. Inheritance

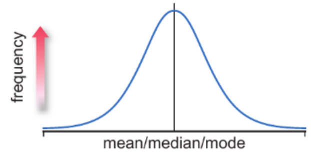
Sex Chromosomes	Female: XX Males: XY
Punnet Squares	Uses the genotypes of male and female gametes to predict the genotypes of the offspring.
Inheriting Sex	
Cystic Fibrosis	Illness that affects the lungs and digestive system caused by inheriting two copies of a faulty recessive allele.
Family Pedigree Chart	Chart showing how genotypes are inherited down through a family. 

6. Gene Mutation

Mutation	A change to the bases in a gene.
Effects of Mutations	Sometimes harmless, can be harmful, very rarely beneficial

Cause of Mutations	Mistakes copying DNA during cell division, DNA damage from chemicals or radiation
Human Genome Project	(HGP) Project involving many scientists from many countries to find the order of bases in human DNA. Allows us to tailor drugs to genes to design better drugs.

7. Variation

Variation	Natural differences between members of a species that affect the chance of survival.
Genetic Variation	Variation caused by genes.
Environmental Variation	Caused by interaction with the surroundings.
Acquired Characteristics	Characteristics caused only by the environment.
Continuous Variation	Data can be any value in a range (height, weight, etc.)
Discontinuous Variation	Data can be a limited set of values (blood group, eye colour, etc.)
Normal Distribution	Bell-shaped curve formed by continuous data with more in the middle and fewer either side. 

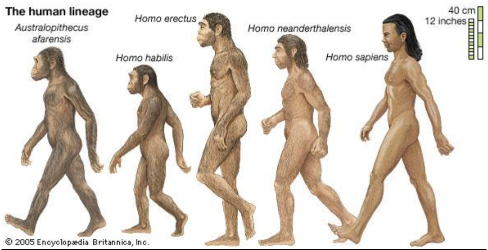
Lesson	Memorised?
1. Meiosis	
2. DNA	
3. DNA Extraction	
4. Alleles	
5. Inheritance	
6. Gene Mutation	
7. Variation	

B4: Evolution

Lesson sequence

13. Human evolution
14. The theory of evolution
15. Resistance
16. Classification
17. How to modify species
18. Problems with modifying species
19. Genetic engineering of bacteria (HT)

1. Human evolution	
***Binomial naming**	Two-part names, first part = genus, second part = species. Written in italics.
****Homo sapiens***	Our species. Evolved about 200,000 years ago. Skull volume 1450 cm^3.
*****Ardipithecus ramidus***	Aka 'Ardi'. 4.4 million years ago, walked upright and climbed trees, 350 cm^3 skull volume.
*****Australopithecus afarensis***	Aka Lucy. 3.2 million years ago, walked upright, skull volume 400 cm^3.
*****Homo habilis***	2.4-1.4 million years ago, walked upright, skull volume 5-600 cm^3.
****8Homo erectus***	1.8 to 0.5 million years ago, walked upright, skull volume 850 cm^3.
***Fossil evidence**	Many fossils have been found showing a gradual transition from 'ape-like' to 'human-like'.
****Stone tool evidence**	Older stone tools are simpler requiring less intelligence to make, younger stone tools are more complex requiring more intelligence to make.
****The Leakeys**	Mary and Louis discovered *Homo habilis*, their son Richard worked on *Homo erectus*.



2. The theory of evolution	
***Charles Darwin**	Develop the theory of evolution.
***Evolution**	The way that species develop by gradual changes over many generations due to natural selection.
***Variation**	Natural differences between members of a species that affect the chance of survival.
****Mutations and evolution**	Changes in DNA cause variation.
****Environmental change**	Change to factors such as food supply, climate or predators.
***Competition**	The fight to eat, survive and breed.
***Natural selection**	Organisms with the best genes and characteristics are more likely to survive, breed and pass on their better genes.
***Inheritance**	Gaining your genes from your parents.
****Well adapted**	An organism has features that make it better able to survive and breed.
****Evolution and the individual**	An individual does not evolve during its lifetime, populations of organisms evolve over many lifetimes.
****Human evolution**	Humans did not evolve from chimpanzees, we both evolved from a common ancestor.

3. Resistance	
***Resistance**	The natural ability of some members of a species to survive poisons that would kill the other members.
***Evolution of resistance**	Evolution of organisms that stops them from being affected by poisons.
****Rats and warfarin resistance**	Warfarin is used to kill rats. Some rats were naturally resistant, survived the warfarin, bred and passed on their resistance genes.
****Antibiotic resistance**	Antibiotics are used to kill bacteria. Some bacteria were naturally resistant, survived the antibiotics, bred and passed on their resistance genes.
****The problems of resistance**	Antibiotic resistance means that many infections that used to be simple to treat may become too resistant to treat, causing major health problems.

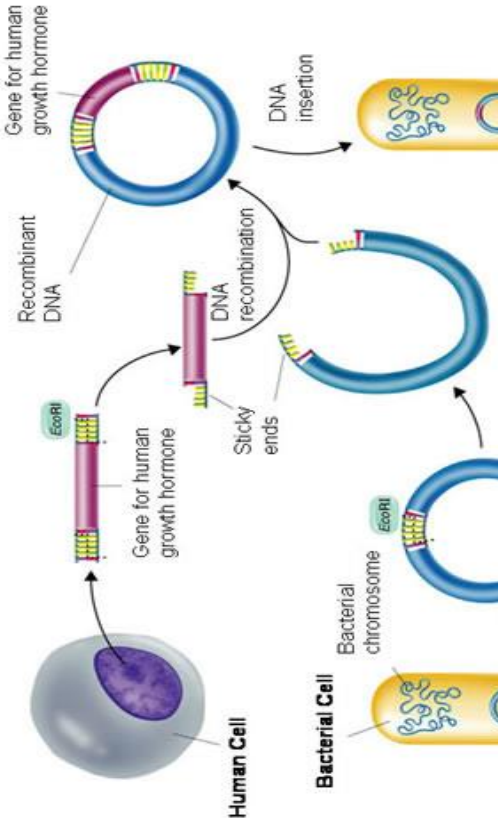
4. Classification	
***Carl Linnaeus**	Developed the modern system of classification.
***How to classify**	Based on similarities, group things into smaller and smaller groups with fewer and fewer similarities.
***Problems with classification**	Sometimes organisms that look similar are not actually related.
***Kingdoms**	Old idea, classifying living things into five kingdoms (including plants, animals and fungi)
****Carl Woese**	Developed the modern system of classification with three domains.
***Domains**	Modern idea of classifying living things into three main groups: bacteria, Archae, Eukarya.
****Bacteria**	Single-celled organisms with no nucleus and no unused sections of DNA.
****Archae**	Single-celled organisms with no nucleus but with unused sections of DNA.
****Eukarya**	(Often) multi-cellular organisms with a nucleus and unused sections of DNA. Includes plants, animals, fungi and protists.

5. How to modify species	
***Artificial selection**	When humans (normally farmers) select the animals/plants to breed with the best characteristics.
***Selective breeding**	Developing new breeds of plants or animals with better characteristics by selective breeding over many generations.
****Selective breeding in practice**	Choose parents with the best characteristics, breed them together, choose from their offspring with the best characteristics, breed them together, repeat for many generations.
***Genetic engineering**	Changing the characteristics of organisms by giving them genes from another organism.
***GMO**	Genetically modified organism: an organism that has had its genes changed.
****Bt corn**	Corn containing a gene from *Bacillus thuringiensis* that makes it produce a substance called Bt which kills insects.
***Medical GMOs**	GM bacteria are used to make insulin (for diabetes) and some antibiotics.
****Pros and cons of GM**	Quicker than selective breeding and can introduce more different characteristics but is expensive.

6. Problems with modifying species	
Over-selection	Farmers focussing too much on breeding for one characteristic (such as chicken breast size), don't spot problems with other characteristics (such as weak leg bones) causing suffering.

Gene leakage	The concern GMOs could breed with wild relatives, enabling the modified genes to escape into the wild. This could have ecological impacts.
Resistance	The concern that in areas growing Bt corn, insects simply evolve resistance to Bt.
Insulin	Insulin made by GM bacteria is not identical to human insulin, and some people suffer bad reactions to it.

7. Genetic engineering of bacteria (HT)	
****Plasmid DNA**	Small loops of DNA containing a few genes.
*****Restriction enzyme**	Enzymes that cut DNA, leaving sticky ends at each end of the piece of DNA.
*****Sticky end**	A short sequence of unpaired bases at the end of a piece of DNA.
*****Ligase**	An enzyme that joins two pieces of DNA by matching up the bases on their sticky ends.
*****Recombinant DNA**	DNA produced by combining together two of more pieces of DNA.
*****How to genetically engineer bacteria**	Cut out gene using restriction enzymes, remove plasmids from bacteria and open with restriction enzymes, use ligase to join gene and plasmid together, return plasmids to bacteria.



B5: Health, Disease & the Development of Medicines

1. Health and Disease

Health	A state of complete physical, social and mental wellbeing.
Physical Health	Being free from disease, active, fit, sleeping well and no substance abuse.
Mental Health	How you feel about yourself.
Social Health	Having healthy relationships and how your surroundings affect you.
Disease	An illness that prevents the body from functioning normally.
Communicable Disease	Diseases caused by pathogens, can be spread from one person to another.
Non-Communicable Disease	Diseases caused by genes or lifestyle. Cannot be spread from one person to another.
Correlated Diseases	Getting one disease increases your chance of another due to diseases weakening organ systems, damaged immune system, and weaker defences.
Pathogen	A microorganisms that causes disease.

2. Non-Communicable Diseases

Genetic Disorders	Diseases caused by inheriting faulty genes from parents.
Malnutrition	Getting too little or too much of a particular nutrient.
Deficiency Disease	Disease caused by the lack of a certain nutrient.
Anaemia	Lack of iron. Causes fewer and smaller red blood cells and low energy.
Kwashiorkor	Lack of protein. Swollen belly, small muscles, stunted growth.
Rickets	Lack of calcium or vitamin D. Causes weak bones leading to bowed legs.
Scurvy	Lack of vitamin C. Swollen bleeding gums, muscle and joint pain, lack of energy.
Drug	Chemical that changes the way the body works.
Cirrhosis	Fatal liver disease caused by drinking too much alcohol over a long period of time.
Impact of Liver Disease / Alcohol	Fifth largest causes of death in the UK, increasing 450% in the last 30 years. Costs £500 million each year to treat.

3. Cardiovascular Disease

Obesity	A condition in which someone is overweight for their height and large amounts of fat builds up around major organs.
Cardiovascular Disease	Disease in which the heart or circulatory system is affected.
Heart Attack	When the heart stops pumping due to a lack of oxygen reaching it.
BMI	Body mass Index $BMI = \frac{\text{(weight in kilograms)}}{\text{height in meters}^2}$ BMI over 30 is obese
Waist:hip Ratio	Waist measurement ÷ hip measurement Better method of measuring abdominal fat which is linked with cardiovascular disease.
Smoking	Harmful substances from smoke can damage blood vessels, increase blood pressure, make blood vessels narrower and increase risk of blood clots.
Stent	A small mesh tube that is inserted into a narrowed artery and opened up to widen it.
Treating Heart Disease with Lifestyle	More exercise and a better diet can treat cardiovascular disease and giving up smoking.

4. Pathogens

Types of Pathogen	Bacteria, virus, protist, fungi.
Tuberculosis	Bacteria. Damages lungs causing bloody cough, fever and weight loss.
Cholera	Bacteria. Sever life-threatening diarrhoea.
Chalara Ash Dieback	Fungi. Kills the leaves of ash trees, killing the tree.
Malaria	Protist. Multiplies inside red blood cells and liver cells and causes fever and weakness.
Haemorrhagic Fever	Virus, e.g. Ebola. Liver and kidney damage, internal bleeding and fever.
HIV	Human immunodeficiency virus attacks white blood cells, causing AIDS.
AIDS	Acquired Immunodeficiency Syndrome. Weakened immune system making simple infections deadly. Caused by HIV.
Hidden Pathogens	Many types of bacteria live in our bodies. Some are essential for health, others may not affect us most of the time. *Helicobacter pylori* can cause stomach ulcers some of the time.

5. Spreading Pathogens

Airborne	Spread through the air. Colds/flus/TB by infected droplets in saliva being passed into the air by coughing or sneezing. Chalara ash dieback by fungal spores carried by wind.
Waterborne	Spread through contaminated water. Cholera
Oral Route	Pathogen enters body through the mouth by eating/drinking.
Vectors	Organisms that carry a pathogen from one person to the next. Mosquitos are vectors for malaria.
Bodily Fluids	Spreading through contact with bodily fluids such as blood or semen. HIV
Hygiene	Keeping things clean to remove or kill pathogens.
Epidemic	When many people over a large area are infected with the same pathogen at the same time.

6. Physical & Chemical Barriers

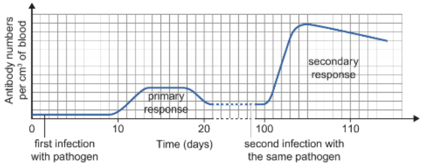
Chemical Defences	Kill pathogens or make them inactive before they can infect us.
Lysozyme	Enzyme found in mucus, tears and sweat that kills some bacteria.
Hydrochloric Acid	Found in the stomach, reducing pH to 2, killing most pathogens.
Physical Barrier	Block or trap pathogens so they cannot enter the body.
Mucus	Sticky secretion that traps pathogens- found in most body openings (nose, mouth, etc.).
Ciliated Cells	Specialised cells with hair like cells that sweep mucus out of the body.
Skin	Blocks pathogens from entering the body.
STIs	Sexually transmitted infections – pathogens spread via sexual activity.
Preventing STIs	Use barrier contraception (such as condoms) to prevent mixing of fluids.
Screening	Large scale testing of people to check if they have an STI so they can be treated. This helps to reduce the spread of STIs.

7. The Immune System

Immune System	Destroys pathogens that manage to infect us.
Antigens	Chemical markers on the surface of pathogens that identify them as a pathogen. Unique to each pathogen.

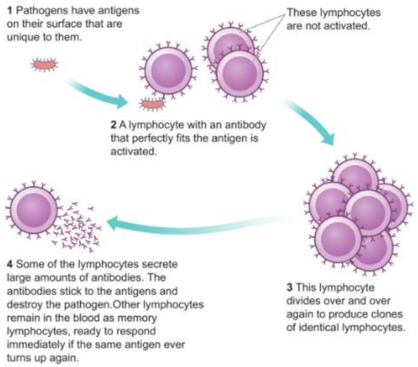
Lymphocyte	White blood cells that produce antibodies. Each lymphocyte produces a different antibody.
Antibodies	Molecules with a specific shape that can attach to a specific antigen on a pathogen and kill it.
Activated Lymphocyte	When an antigen sticks to an antibody, it activates the lymphocyte causing it to make many copies of itself that make the same antibodies.
Memory Lymphocyte	Lymphocytes left over after an infection that retain the ability to fight the pathogen.
Immune	The body has memory lymphocytes to fight the pathogen if it returns so it can't be harmed by it.

Primary Response vs. Secondary Response



Vaccine	A weakened or inactive version of a pathogen.
How vaccines work	Vaccines are harmless versions of pathogen that still have the antibodies on them, so the immune response is triggered without any risk of disease.

How the Immune System Attacks Pathogens



8. Antibiotics	
Antibiotics	Substances that kill bacteria or inhibit their processes without harming human cells.
Penicillin	The first antibiotic discovered by Alexander Fleming. Produced by a mould.
Resistance	Widespread use of antibiotics has led to resistance, meaning many antibiotics don't work as well as they once did.
Drug Development	Developing new medicines involves many stages that take a lot time and money.
Discovery Phase	Developing new chemicals that might work as medicines.
Pre-Clinical Phase	Testing on cells grown in the lab, or on animals, to see if the chemical has any useful effect.
Small Clinical Trial	Testing on a few healthy people to check for safety.
Large Clinical Trial	Testing on many patients to discover how effective the drug is and determine the dose.
Side Effects	Unwanted effects of the medication that can be quite harmful.
Dose	The correct amount of the medicine that needs to be given to the patient.

Lesson	Memorised?
1. Health and Disease	
2. Non-Communicable Diseases	
3. Cardiovascular Disease	
4. Pathogens	
5. Spreading Pathogens	
6. Physical & Chemical Barriers	
7. The Immune System	
8. Antibiotics	

C3 & 4: Atoms and the periodic table

Lesson sequence

20. Structure of atoms
21. Detailed structure of atoms
22. Isotopes
23. Mendeleev's periodic table
24. The modern periodic table
25. Electron configuration

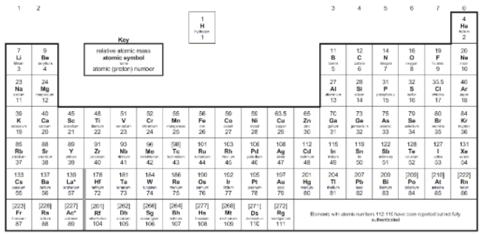
1. Structure of atoms	
***Particle**	The tiny pieces that all matter is made from.
***Atom**	The smallest independent particle. Everything is made of atoms.
****Size of atoms**	About 1 x 10^{-10} m in diameter.
****Dalton's model of atoms**	- Tiny hard spheres - Can't be broken down - Can't be created or destroyed - Atoms of an element are identical - Different elements have different atoms
***Subatomic particles**	Smaller particles that atoms are made from.
***Proton**	Mass = 1 Charge = +1 Location = nucleus
***Neutron**	Mass = 1 Charge = 0 Location = nucleus
***Electron**	Mass = 1/1835 (negligible) Charge = -1 Location = shells orbiting nucleus
***Nucleus**	Central part of an atom, 100,000 times smaller than the overall atom

2. Detailed structure of atoms	
****Alpha particle**	Small positively charged particle made of two protons and two neutrons.
****Scattering**	When particles bounce back or change direction.
****Rutherford's experiment**	Fired alpha particles at gold leaf, used a phosphor-coated screen to track where they went.
****Rutherford's results**	Most alpha particles went through, some scattered (changed direction).
****Rutherford's explanation**	Scattered particles hit a solid nucleus. Most did not hit it, therefore nucleus is small
***Atomic number**	The bottom number on the periodic table, gives the number of protons and electrons.
***Atomic mass**	The top number on the periodic table, gives the total protons and neutrons together.
***Number of protons**	The atomic number.
***Number of electrons**	The atomic number.
***Number of neutrons**	Atomic mass minus atomic number.
***Number of protons and electrons**	Equal, because each negative electron is attracted to a positive proton in the nucleus.

3. Isotopes	
****Isotopes**	Atoms with the same number of protons but different number of neutrons.
****Describing isotopes**	Mass after the name (e.g. boron-10) or superscript mass before the symbol (^{10}B).
***Nuclear fission**	Large unstable atoms break into two smaller stable ones.
****Uses of fission**	Nuclear power, nuclear weapons.
****Relative atomic mass, A_r**	The weighted average of the masses of all of the isotopes of an element.
*****Isotopic abundance**	The percentage of an element that is made of a particular isotope.
*****Calculating A_r**	- Multiply each mass by the decimal % - Add these up **Note:** (decimal % = %/100)

4. Mendeleev's periodic table	
***Dmitri Mendeleev**	Russian chemist, developed the periodic table.
***Mendeleev's periodic table**	Ordered by increasing A_r, some elements switched according to their properties.
***Chemical properties**	Includes reaction with acid and formula of oxide.
***Physical properties**	Includes melting point and density.
****Gaps in Mendeleev's periodic table**	Mendeleev left gaps where no known element fitted and predicted these would be filled with newly discovered elements.
****Eka-aluminium**	An element that Mendeleev thought would fill a gap. He predicted its properties, which matched gallium when discovered.

5. The modern periodic table	
***Noble gases**	Gases that do not react: He, Ne, Ar, Kr.
****Moseley's experiment**	Fired electrons at samples of elements and measured X-rays produced.
****Moseley's results**	Energy of x-rays produced proportional to the positive charge of the element.
****Conc. from Moseley's work**	The atomic number must be the number of protons in the atoms.
****Pair reversals**	Elements (like Ar and K) that are not in order of increasing mass.
****Explaining pair reversals**	It means elements should be order elements by increasing atomic number instead.



6. Electron configuration	
***Shells**	Electrons orbit atoms in shells.
***First shell**	Holds up to two electrons.
***Second shell**	Holds up to eight electrons.
***Third shell**	Holds up to eight electrons.
***Number of electrons**	Given by the atomic number.
***Filling shells**	Fill shells from the first shell out. Move up a shell when current one is full.
***Electron configuration**	The number of electrons in each shell (e.g. Al is 2.8.3).
***Outer shell**	The last shell with any electrons in it.
****Groups**	Columns in the periodic table, tell you the number of electrons in the outer shell.
****Periods**	Rows in the periodic table, tell you the number of electron shells.

C5-7: Bonding

Lesson sequence

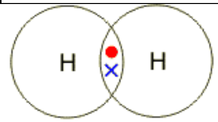
26. Ionic bonding
27. Ionic compounds
28. Properties of ionic compounds
29. Covalent bonding
30. Covalent structures
31. Allotropes of carbon
32. Metallic bonding
33. Classifying materials

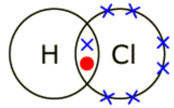
1. Ionic bonding	
***Bond**	An attraction between two atoms that holds them together.
***Ion**	An atom that has gained a charge by gaining or losing electrons.
***Charge**	Whether an ion is positive or negative.
***Cation**	Positive ion formed by losing electrons. Formed by metal atoms.
***Anion**	Negative ion formed by gaining electrons. Formed by non-metal atoms.
****Size of charge**	The number of electrons transferred affects the size of charge: losing two electrons makes a 2+ charge, gaining three electrons makes a 3- charge.
****How many electrons are gained or lost?**	**Metals:** however many electrons are in the outer shell **Non-metals:** however many electrons are needed to fill the outer shell.
***Electrostatic force**	A force of attraction between a positive and negative particle.
***Ionic bond**	When two oppositely charged ions are held together by an electrostatic force.
****Forming ionic bonds**	Electrons are transferred from a metal atom to a non-metal atom to form a positive metal cation and a negative metal anion. The oppositely charged ions are attracted to each other.

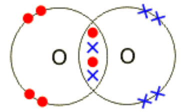
2. Ionic compounds	
***Chemical formula**	Shows the number of atoms of each element present in one 'unit' of a compound.
***Writing formulae**	- Each chemical symbol starts with a capital letter. - The number of each atom present is shown with a subscript number after the symbol. E.g. H_2SO_4.
****Determining ionic formulae**	- Ensure the total number of positive and negative charges balance. - Change the number of each ion present by changing the subscript numbers.
***Compound ions**	An ion made from two or more atoms that share a charge.
***Common compound ions**	Hydroxide: OH^- Nitrate: NO_3^- Sulfate: SO_4^{2-} Sulfite: SO_3^{2-} Carbonate: CO_3^{2-} Ammonium: NH_4^+
****Including compound ions in formulae**	If you need more than one, put brackets around it. E.g. $Mg(OH)_2$
***Ionic lattice**	The structure of ionic compounds: a repeating 3D pattern of alternating positive and negative ions.
****Crystal**	A piece of material with a regular shape and straight edges formed by the regular pattern of ions in an ionic lattice.

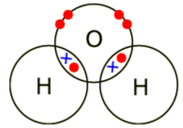
3. Properties of ionic compounds	
****Melting point of ionic compounds**	High because melting needs a lot of energy to break strong ionic bonds.
***Solubility of ionic compounds**	Many ionic compounds dissolve in water.
****Electrical conductivity of ionic compounds**	Solid: Do not conduct because ions can't move. Liquid (molten or solution): Do conduct because ions can move.
****How ionic compounds conduct electricity**	When they are in a liquid form, the positive cations move to the negative electrode (cathode) and the negative anions move the positive electrode (anode).

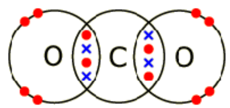
4. Covalent bonding	
***Covalent bond**	An electrostatic attraction between two atoms and a share pair of electrons.
****Double bond**	A covalent bond involving two shared pairs of electrons.
***Dot and cross diagram**	A bonding diagram showing the electrons in the outer shell of each atom, with electrons drawn as dots or crosses.
***Hydrogen, H_2**	Two overlapping circles both labelled H. One pair in the overlap.
****Hydrogen chloride, HCl**	Two overlapping circles labelled H and Cl. One pair in the overlap, 6 electrons around Cl.
****Oxygen, O_2**	Two overlapping circles both labelled O. Two pairs in the overlap, 4 electrons around each O.
****Water, H_2O**	Three overlapping circles in a line labelled H, O, H. A pair in each overlap, 4 electrons around O.
****Carbon dioxide, CO_2**	Three overlapping circles in a line labelled O, C, O. Two pairs in each overlap, 4 electrons around each O.
****Methane, CH_4**	Five circles with one in the centre labelled C and 4 labelled H around it. A pair in each overlap.
****Valency**	The number of covalent bonds an atom can form.
****Valency and groups**	Group 4 = 4 (4 electrons needed) Group 5 = 3 (3 electrons needed) Group 6 = 2 (2 electrons needed) Group 7 = 1 (1 electron needed)
****Working out molecular formulae**	Find the lowest common multiple of the valency of each atom. Use the number of an atom required to reach the LCM.

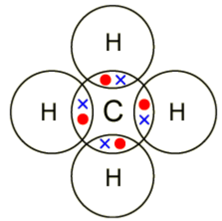








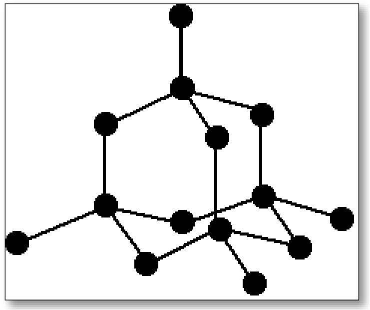


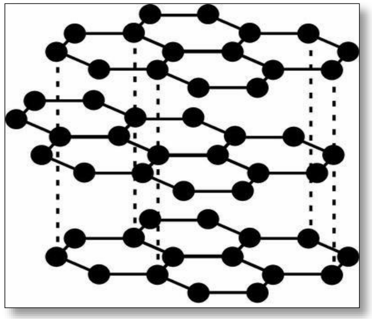


5. Covalent structures	
***Molecule**	A particle made from two or more atoms bonded together.
***Simple molecular structure**	A structure made of small molecules in which a few atoms join together to form a small particle.
****Structure of molecular substances**	Atoms in a molecule are held together by strong covalent bonds. Neighbouring molecules are held close by weak intermolecular forces.
****Intermolecular force**	A weak electrostatic force that holds two neighbouring molecules together.
****Melting point of simple molecular compounds**	Low because melting only needs a little energy to break weak intermolecular forces.
****Electrical conductivity of simple molecular compounds**	Do not conduct because there are no electrons that are free to move.
***Examples of simple molecular substances**	Hydrogen gas, oxygen gas, water, carbon dioxide, methane.
***Giant molecular structure**	A structure made of a repeating pattern of atoms covalently bonded together.
****Melting point of giant molecular compounds**	High because melting requires breaking strong covalent bonds.
****Electrical conductivity of simple molecular compounds**	Do not conduct (except graphite) because there are no electrons free to move.
***Examples of simple molecular substances**	Silicon dioxide (silica), diamond, graphite.
***Polymer**	A large molecule made of a small unit repeated many times.
***Monomer**	A small molecule that can be joined together many times to form a polymer.

6. Allotropes of carbon	
***Allotrope**	A different structural form of an element made of the same atoms just bonded together differently.
***Carbon's allotropes**	Graphite, diamond, graphene, fullerenes
****Graphite**	**Structure:** stacked sheets of carbon in a honeycomb pattern with delocalised electrons between them. **Properties:** sheets slide apart easily, excellent conductor **Uses:** lubricants
****Diamond**	**Structure:** Repeating pattern of 4 atoms bonded to 4 others. **Properties:** Extremely hard. **Uses:** Cutting tools and drills
****Graphene**	**Structure:** A single layer of atoms in a honeycomb pattern. **Properties:** Very strong, excellent conductor. **Uses:** None yet, but potentially many.
****Buckminster fullerene**	**Structure:** Ball-shaped molecules of C_{60}. **Properties:** Low melting point **Uses:** None
****Carbon nanotubes**	**Structure:** Cylinders made of carbons bonded in a honeycomb pattern. **Properties:** Very strong, excellent conductors **Uses:** Strong and flexible materials, electronics.

7. Metallic bonding	
***Structure of metals**	A lattice of positive metal ions surrounded by a cloud of delocalised electrons.
****Delocalised electrons**	Electrons that are not bound to a single atom but move freely around many.
****Metallic bonding**	The electrostatic attraction between the lattice of positive metal ions and the cloud of delocalised electrons.





****Electrical conductivity of metals**	Metals are good conductors because the electrons are free to move.
****Comparing the conductivity of metals**	Metals with more electrons in the outer shell – such as Al – are better conductors than those with fewer – such as Li – because there are more delocalised electrons that are able to move.
***Malleable**	When a substance dents when it is hit instead of shattering.
****Malleability of metals**	Metals are malleable because the atoms are arranged in regular sheets and these sheets can easily slide over each other when hit.
****Melting point of metals**	High because melting them requires breaking the strong force of attraction between the lattice of metal ions and the cloud of delocalised electrons.

8. Bonding models	
****Classifying materials**	The properties of a material can be used to determine the type of bonding in it.
****Properties of ionic compounds**	High melting point, often soluble in water, solid does not conduct electricity, liquid/solution does.
****Properties of simple molecular compounds**	Low melting point, does not conduct electricity, sometimes soluble in water.
****Properties of giant molecular compounds**	High melting point, does not conduct electricity (except graphite), insoluble in water.
****Properties of metallic compounds**	High melting point, does conduct electricity, insoluble in water.
****Bonding models**	The ideas and drawings that we use to explain the bonding of atoms.
****Problems with bonding models**	- Dot and cross diagrams make electrons seem different, they are not - Atoms appear stationary but are actually vibrating - Atoms don't appear to be touching when they actually are.

CC9: Quantitative chemistry

Kettering Science Academy

1. Relative Formula masses

Molecular formula	Gives the number of atoms of each element present in a molecule.
Empirical formula	The **simplest ratio** of the atoms of each element present in a compound.
Converting molecular to empirical formulae	Divide the number of each atom by the highest common factor of all of the atoms.
Molecular to empirical formula examples	C_4H_8 ← write the formula 4 : 8 ← write as a ratio $\frac{4}{4}:\frac{8}{4}$ ←divide by small number 1 : 2 ← simplest ratio CH_2 ← write as formula
Relative atomic mass, Ar	The mass of an atom relative to 1/12th the mass of carbon-12. No units.
Relative formula mass, Mr	The mass of one unit of a formula, found by adding the relative atomic masses of all of the atoms in it.

2. Calculating empirical formulae

Steps to calculate empirical formulae from experimental data	1) Write each element's symbol with a ratio (:) symbol between 2) Write out the amount of each element from the questions 3) Divide each amount by the **A_r** of the element 4) Divide each answer by the **smallest number** to get a ratio 5) Write the empirical formula
To find a molecular formula from an empirical formula	1) Calculate M_r for the empirical formula 2) Divide the M_r of the molecular formula by this number 3) Multiply the empirical formula by your answer

Empirical formula example

A compound contains 14.3% hydrogen by mass and 85.7% carbon. Determine its empirical formula.

Symbols:	C	:	H
Amounts:	85.7%		14.3%
by A_r:	85.7 ÷ 12 = 7.14		14.3 ÷ 1 = 14.3
÷ by smallest:	7.14 ÷ 7.14 = 1		14.3 ÷ 7.14 = 2
Write formula:	CH_2		

The relative formula mass of the compound is 28, determine its molecular formula.

M_r of empirical: $M_r(CH_2)$ = 12 x 1 + 1 x 2 = 14
÷ molecular M_r by empirical M_r: 28 ÷ 14 = 2
Multiply empirical formula: CH_2 x 2 = C_2H_4

3. Magnesium Oxide Experiment

Equipment	Crucible (small pot capable of withstanding high heat) Clay triangle (to put the crucible on because a gauze would melt)
Method	1) Weigh small amount of magnesium ribbon 2) Heat in a **crucible** to react with air 3) Reweigh once cool to find new mass.
Results	It gets heavier because the oxygen has been added to the solid
Analysis	Find the mass of oxygen added by doing **new mass – old mass.** **Then do the empirical formula calculation**
Magnesium Oxide	Is MgO

3. Conservation of mass

Conservation of mass	The total mass of products must equal the total mass of reactants.
Precipitation reaction	A reaction that produces An insoluble solid precipitate by mixing two solutions.
Closed system	A system in which no chemicals can enter or leave, such as a sealed test tube.
Open system	A system in which chemicals can enter or leave – such as an open test tube.
Conservation of mass in a closed system	No atoms are able to enter or leave - total mass stays the same. Example: precipitation in a closed flask.
Conservation of mass in an open system	Atoms can leave – total mass appears to change. Example: a carbonate reacting with acid producing CO_2 bubbles: the mass appears to decrease because you can't weigh the gas that goes into the air, however it is still there.

4. Calculating reacting masses

Excess reactant	Any reactant which is not used up completely in a reaction because there is more of it than needed.
Limiting reactant	Any reactant which is completely used up in a reaction. The limiting reactant determines how much product is made because it will run out of this then stop.
Stoichiometry	Means the balancing of an equation. Use the **limiting reactant** to work out how much is made from balancing.
Calculating reacting masses	1) Write out the balanced equation 2) Calculate the RFMs 3) Write the RFMs as a **ratio** 4) Divide both sides of the ratio by the RFM of the chemical you know the mass of 5) Scale up or down
Calculate concentration	Concentration = $\frac{\text{mass in g}}{\text{volume in dm}^3}$
Convert cm^3 to dm^3	$\frac{cm^3}{1000} = dm^3$

Reacting masses example

What mass of iron can be produced from 50 g of iron oxide (Fe_2O_3)?

$2Fe_2O_3 + 3C$	→	$4Fe + 3CO_2$
320	:	224
$\frac{320}{320}$	:	$\frac{224}{320}$
1	:	0.7
1 × 50	:	0.7 × 50
50g	:	**35g**

RFM calcs: **2 Fe_2O_3:** 2 x (2 x 56 + 3 x 16) = 320
4 Fe: 4 x 56 = 224

5. Moles (HIGHER ONLY)

Moles	Measures **amount of substance** – one mole of any chemical is the same amount.
One mole is…	The Avogadro number of particles (atoms, ions or molecules)
One mole is also…	The mass in grams of its relative formula mass.
Avogadro's constant	6.02×10^{23}: the number of atoms/molecules present in one mole of a substance.
Calculating moles from mass	moles = $\frac{\text{mass}}{\text{relative formula mass}}$
Calculating moles from a number of particles	Quantity in moles = $\frac{\text{no.particles}}{6.02 \times 10^{23}}$
Calculating the number of particles from moles	No. particles = moles x 6.02×10^{23}

Lesson	Memorised?
1. Relative Formula Masses	
2. Calculating Empirical Formulae	
3. Conservation of mass	
4. Reacting masses	
5. Moles	

CC13: Groups in the Periodic Table

1. Group 1

Alkali metals	The name we give to group 1 – lithium, sodium, potassium and so on.
Group 1 symbols	Li – lithium Na – sodium K – potassium
Properties of alkali metals	- soft - relatively low melting points
Reaction of alkali metals with water	Metal + water → metal hydroxide + hydrogen E.g: sodium + water → sodium hydroxide + hydrogen $2Na + 2H_2O \rightarrow 2NaOH + H_2$
Lithium and water	Floats. Bubbles (of hydrogen). Moves slowly.
Sodium and water	Floats. Melts. Bubbles (of hydrogen). Moves more quickly
Potassium and water	Floats. Melts. Bubbles (of hydrogen) **catch fire (lilac flame)**. Moves very quickly
Group 1 reactivity	Reactivity increases as you move down the group.
Explaining group 1 reactivity	When metals react they **lose** their outer electrons. Further down the group there are: - **more** shells of electrons - so the outer electrons are **further** from the nucleus - so outer electrons are **less attracted** to the nucleus - so outer electrons are **easier to remove.** OPPOSITE PATTERN TO GROUP 7

2. Group 7

Halogens	The name given to group 7 – fluorine, chlorine, bromine and iodine.
Chlorine	Cl_2. A pale green gas.
Bromine	Br_2. A red-brown liquid.
Iodine	I_2. A shiny purple-black solid.
Reaction of halogens with metals	Halogen + metal → metal halide E.g: Bromine + sodium → sodium bromide $Br_2 + 2Na \rightarrow 2NaBr$
Reaction of halogens with hydrogen	Halogen + hydrogen → hydrogen halide E.g: Chlorine + hydrogen → hydrogen chloride $Cl_2 + H_2 \rightarrow 2HCl$
Hydrogen halides	Hydrogen halides dissolve in water to form acids, for example hydrogen chloride makes hydrochloric acid.
Chlorine test	Chlorine gas turns **damp blue litmus red** then quickly bleaches it **white**.

3. Reactivity of halogens

Group 7 reactivity	Reactivity increases as you go up the group.
Explaining group 7 reactivity	When non-metals react they complete their outer shells. Going up the group there are: - **less** shells of electrons - so the outer electrons are **closer** to the nucleus - so outer electrons are **more attracted** to the nucleus - so **more able to hold** an extra outer electron OPPOSITE PATTERN TO GROUP 1
Displacement reactions	Reactions in which a more reactive metal displaces a less reactive metal from a salt eg: *copper sulfate + zinc → zinc sulfate + copper* Does not work backwards as copper is less reactive than zinc.
Displacement reactions of halogens	A **more** reactive halogen displaces a **less** reactive halide ion by taking its electrons. E.g: bromine + sodium iodide → iodine + sodium bromide $Br_2 + 2NaI \rightarrow I_2 + 2NaBr$ [bromine more reactive]
Redox reactions of halogens	Displacement reactions are REDOX because the more reactive halogen **oxidises** the less reactive halide by **taking its electrons**. The more reactive halogen is reduced. E.g: $Br_2 + 2I^- \rightarrow 2Br^- + I_2$
OIL RIG	**O**xidation **I**s **L**oss (of electrons) **R**eduction **I**s **G**ain (of electrons)

4. Group 0

Noble gases	The name given to group 0 – helium, neon, argon, krypton and xenon.
Melting point of noble gases	They are all gases at room temperature but the melting and boiling point increase down the group.
Reactivity of group 0	The noble gases do not (easily) do any reactions – they are inert.
Explaining reactivity of group 0	When elements react they try to complete their outer shells. Because group 0's outer shells are already complete, they do not react.
Uses of noble gases	-Helium is used in airships because it is inert and has low density - Argon is used in fire extinguishers because it is inert and denser than air. - Neon is used in lighting because it glows red when electricity is passed through it.

Lesson	Memorised?
1. Group 1	
2. Group 7	
3. Reactivity of halogens	
4. Group 0	

C14 Rates of Reaction

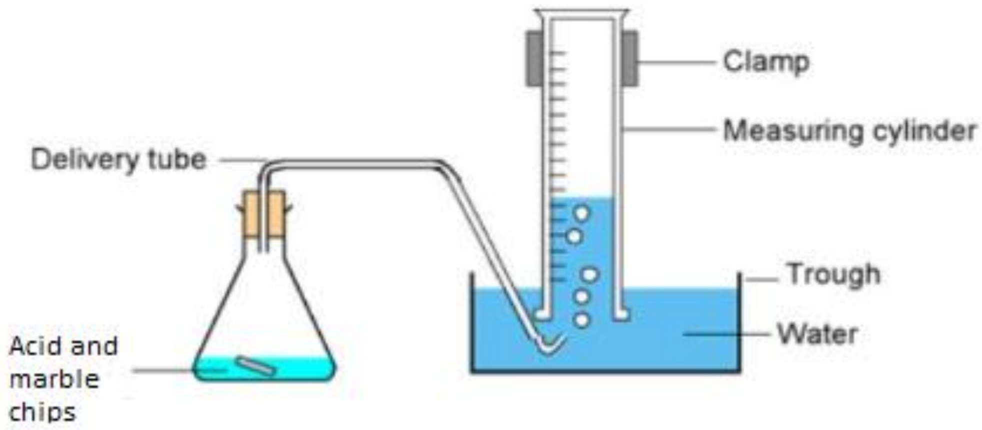
Lesson sequence

34. Rates of reaction
35. Collision theory
36. Core practical – rates of reaction (CP11)
37. Catalysts

1. Rates of reaction	
***Rate of reaction**	The rate at which reactants are used up or products are made.
***Reactants vs time graph**	Starts high and curves downward, decreasing rapidly at first and then more gently. Steeper line = faster rate.
***Products vs time graph**	Starts low and curves upwards, increasing rapidly at first and then more gently. Steeper line = faster rate.
****Measuring rates – reactions that produce gas**	- Collect gas in a gas syringe and measure the volume every 30 secs. - Collect gas over water (up-turned measuring cylinder full of water) and measure volume every 30 secs. - Do reaction on a balance and record the change in mass every 30 secs.
****Measuring rates – reactions that go cloudy**	Do the reaction in a beaker placed on piece of paper with a cross marked on it. Looking down through the beaker, time how it takes for the cross to disappear.

2. Collision theory	
***Collision theory**	States that for two particles to react they must: - Collide with each other - Collide with enough energy to react
***Activation energy**	The minimum energy that two particles must have when they collide in order to react.

****Effect of concentration on rate**	• Increased concentration means that there are more particles **in the same volume** • So there are more collisions **per second**. • So a faster reaction
****Effect of surface area on rate**	• Increased surface area means that there are more particles **at the surface able to collide** • So there are more collisions **per second**. • So a faster reaction
****Effect of pressure on rate**	• Increased gas pressure means that there are more particles **in the same volume** • So there are more collisions **per second**. • So a faster reaction
****Effect of temperature on rate**	• Increased temperature means that that particles have a higher kinetic energy and **move faster** • So there are more collisions **per second**. • But these collisions **also are at higher energy** so more collisions result in reactions • So a faster reaction



3. Core practical – rates of reaction (CP11)

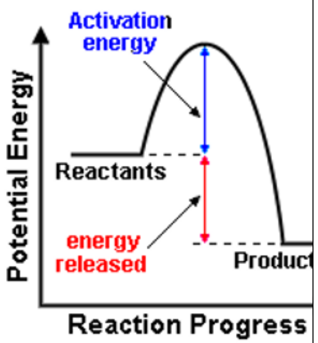
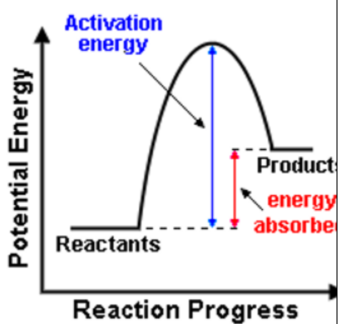
***CP11 – Aim**	To explore how particle size and concentration affect the rate of reaction
***CP11 – Gas collection – setup**	See diagram
***CP11 – Gas collection – measurements**	Record the volume of gas collected few seconds until it stops.
***CP11 – Gas collection – independent variable**	Repeat with a different size of marble chips.
***CP11 – Gas collection – results**	The amount of gas collected increases quickly at first and then more slowly. The smaller marble chips produce gas more quickly, but the same amount in total.
***CP11 – similar experiments**	You could keep the chip size the same and use different temperatures, or different concentrations
***CP11 – common problems**	Gas escaping, so the reaction looks slower than it really is
***CP11 – improvements**	Use a gas syringe (CO_2 dissolves in water so you don't get a perfect reading)
***CP11 – Colour change – setup**	Draw a cross on a piece of paper and place a beaker on it. Measure out 50 cm^3 of sodium thiosulfate solution and 5 cm^3 of hydrochloric acid into two test tubes and leave to warm in a water bath at 30^{o}C.
***CP11 – Colour change – run the experiment**	Quickly pour both test tubes into the beaker, mix and start the stopwatch. Looking down through the beaker, stop when you can no longer see the cross.
***CP11 – Colour change – independent variable**	Repeat with water baths set to 35^{o}C, 40^{o}C, 45^{o}C and 50^{o}C.
***CP11 – Colour change – results**	The cross disappears most quickly at 50^{o}C and least quickly at 30^{o}C.

4. Catalyst	
***Catalyst**	A substance that speeds up a chemical reaction without being used up.
****Effect of catalysts on rate**	Catalysts increase the rate of reaction by reducing the activation energy so that a greater proportion of collisions lead to reactions.
****Reaction profile**	A graph that shows the changes in energy during a reaction. Starts with large 'hump' that represents the activation energy.
****Effect of catalysts on reaction profiles**	The 'hump' representing the activation energy is smaller.
***Enzyme**	A protein that works as a catalyst to speed up the reactions in our cells.
***Enzymes in alcohol production**	Alcoholic drinks are produced using enzymes found in yeast which catalyse a reaction that turns glucose into ethanol.

CC15: Groups, rates and heat changes

Lesson sequence

38. Exothermic and endothermic reactions
39. Explaining energy changes

1. Endothermic and exothermic reactions	
***Exothermic reaction**	A reaction that transfers energy to the surroundings (gets hotter, temperature **up**).
***Endothermic reaction**	A reaction that absorbs energy from the surroundings (gets colder, temperature **down**)
****Exothermic reaction profile**	 Exothermic reaction
****Endothermic reaction profile**	 Endothermic reaction

****Measuring energy changes**	-Sit a polystyrene beaker inside a glass beaker (insulation) - Measure the starting temperature of the reactants. - Mix the reactants in the polystyrene beaker - Cover with lid fitted with a thermometer - Monitor and record the peak temperature change.
**** Most common problem**	Heat escaping. Solution is more insulation.

2. Explaining energy changes	
****Chemical bonds in reactions**	During chemical reactions, old chemical bonds are broken and new ones are formed.
****Breaking bonds**	**Endothermic.** Breaking bonds absorbs energy, breaking stronger bonds absorbs more energy.
****Making bonds**	**Exothermic.** Making bonds releases energy, making stronger bonds releases more energy.

****Energy changes and bond formation**	The energy change in a reaction is the difference between the energy required to break the old bonds and the energy released by making the new ones.
****Exothermic reactions and bonds**	Exothermic reactions break weaker bonds and make stronger ones.
****Endothermic reactions and bonds**	Endothermic reactions break stronger bonds and make weaker ones.
*****Bond strength**	The energy required to break one mole of a particular covalent bond in kJ/mol.
*****Calculating energy changes from bond strengths**	Add up the total strength of old bonds broken and subtract the total strength of new bonds made. A negative answer is exothermic.

C16 Fuels / C17 Earth and Atmospheric science

Kettering Science Academy

C16a Hydrocarbons in crude oil and natural gas

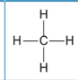
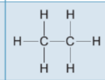
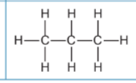
Hydrocarbon	A compound containing only hydrogen and carbon atoms.
Crude oil	A thick brown liquid made of a mixture of many different hydrocarbons found in deposits underground.
Crude oil as a finite resource	There is a limited amount: at some point, it will run out.
Molecules in crude oil	Hydrocarbons in many different forms with carbons joined together into both chain- and ring-shaped molecules.
Properties of hydrocarbons in crude oil	Most of the hydrocarbons in crude oil are liquids, but each of them has a different boiling point.
Hydrocarbons in crude oil	Mostly alkanes.
Non-renewable	A resource that will eventually run out.
Uses of crude oil	Fuel, feedstock (supply of basic chemicals) for the chemical industry.

C16b Fractional distillation of crude oil

Fractional distillation	A type of distillation used to separate mixtures of two or more liquids.
Separation in fractional distillation	Fractional distillation separate compounds according to their boiling point.
Heating crude oil	Crude oil is passed through a heater to heat it to about 400°C so that nearly everything is a gas.
Separating crude oil in a fractionating column	The hot gases rise up the fractionating column until cool enough to condense.
Fractions of crude oil	The separated liquids and gases collected at different temperatures. The main ones are gases, petrol, kerosene, diesel oil, fuel oil, and bitumen.
Fractions in order	Gases, petrol, kerosene, diesel, fuel oil, bitumen: - Smallest to biggest molecules - Lowest to highest boiling point - Lowest to highest viscosity - Easiest to hardest ignition
Viscosity	How easily a fluid flows – higher viscosity = runnier.
Ease of ignition	How easily a substance catches fire.
Gases	Used for domestic heating and cooking.
Petrol	Used as a fuel for cars.
Kerosene	Fuel for aircraft.
Diesel oil	Fuel for larger vehicles such as lorries and trains.
Fuel oil	Fuel for large ships and power stations.
Bitumen	Surfacing roads and roofs.

C16c The alkane homologous series

Homologous series	A family of closely related compounds with molecular formulae that differ only in the number of 'CH_2's.
Physical properties in a homologous series	Vary gradually, for example the boiling point gradually increases.
Chemical properties in a homologous series	Very similar with a gradual variation.
General formula	Describes the number of each atom in any member of a homologous series.
Alkanes	Hydrocarbons containing only single bonds. The names end with '-ane'.
First three alkanes	Methane – CH_4 Ethane – C_2H_6 Propane – C_3H_8
General formula of alkanes	C_nH_{2n+2}

Name	Molecular formula	Structural formula
methane	CH_4	
ethane	C_2H_6	
propane	C_3H_8	

C16d Complete and incomplete combustion

Combustion	When a compound reacts with oxygen producing a flame.
Complete combustion	Combustion that produces only water and carbon dioxide and releases the most possible energy.
Complete combustion equation	Fuel + oxygen → carbon dioxide + water E.g: Ethane + oxygen → carbon dioxide + water $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
Carbon dioxide test	Limewater turns milky/cloudy.
Incomplete combustion	Combustion that produces a mixture of carbon dioxide, carbon monoxide, carbon and water and produces less energy.
Why incomplete combustion happens	When there is not enough oxygen for all of the reactants to be fully oxidised.
Carbon monoxide	CO. A colourless odourless a highly toxic gas.
How carbon monoxide kills	It sticks to haemoglobin in the blood, which prevents it from carrying oxygen.
Soot	The small particles of carbon produced by incomplete combustion.
Problems with soot	- Causes lung problems when breathed in. - Blackens and dirties buildings.
Preventing incomplete combustion	It is important that boilers at home have a good air supply to prevent incomplete combustion. For this reason, a boiler's flue pipe should be checked for blockages every year.

C16e Combustible fuels and pollution

Sulfur	An impurity that is naturally present in small amounts in oil and coal.
Sulfur dioxide	SO_2. A gas formed from the sulfur in oil and coal when it is burnt.
Acid rain	Rain with a pH lower than 5.2
Formation of acid rain	Sulfur dioxide dissolves in water in clouds to form sulfurous acid (H_2SO_3) which oxidises to become sulfuric acid (H_2SO_4).
Effects of acid rain	- Soil becomes too acidic for crops and plants to grow well. - Acid in rivers and lakes prevents fish eggs from hatching and kills some insects. - Acid rain increases corrosion of limestone, which damages buildings and statues.
Nitrogen oxides	NO_x. Various gases formed at high temperatures inside internal combustion engines.
Problems of nitrogen oxides	- Can dissolve in clouds to form acid rain - NO_2 causes lung damage - NO_x can cause smog to form

C16f Breaking down hydrocarbons

Cracking	Breaking down longer less useful hydrocarbons into shorter more useful ones.
How to crack hydrocarbons	Heat the hydrocarbons and pass the vapours over an aluminium oxide catalyst heated to 650°C.
Products of cracking an alkane	An alkane and an alkene. E.g: Hexane → butane + ethene $C_6H_{14} \rightarrow C_4H_{10} + C_2H_4$
Alkene	A hydrocarbon containing a C=C double bond.
Usefulness of cracking	There is more demand for shorter hydrocarbons – such as petrol and gas – than longer ones such as bitumen. Cracking turns the less useful ones into more useful ones.
Hydrogen gas as a fuel	H_2. Hydrogen has the potential to be used as a fuel for cars.
Advantages of hydrogen as a fuel	- It only produces H_2O when burnt so does not directly contribute to global warming - It can be produced using renewable energy
Disadvantages of hydrogen as a fuel	- Most of it is currently produced in ways that also produce CO_2 which contributes to global warming - It is difficult to store

C17a The early atmosphere

The early Earth	4.5-3.5 billion years ago the Earth was extremely hot and there were many volcanoes.
The early atmosphere	Little or no oxygen, a lot of carbon dioxide, water vapour, small amounts of other gases such as nitrogen.
Origin of the early atmosphere	Gases from volcanoes.
Evidence for a lack of oxygen	The oldest rocks on Earth contain compounds such as iron pyrite that cannot form in the presence of oxygen.
Formation of the oceans	As the Earth cooled, water vapour in the air condensed to liquid water, forming the oceans.

C17b The changing atmosphere

Changes to the atmosphere	The amount of carbon dioxide decreased, water vapour decreased, oxygen increased.
Photosynthesis and the atmosphere	Photosynthesis – by cyanobacteria and plants – consumes carbon dioxide (decreasing it) and produces oxygen (increasing it).
Oceans and carbon dioxide	Carbon dioxide dissolves in the ocean and is used by sea creatures to make their shells, enabling even more CO_2 to dissolve.
Test for oxygen	A glowing splint (stick) placed in oxygen will relight.

C17c The atmosphere today

Greenhouse effect	Infrared radiation (heat) from the sun travels through the atmosphere and warms the ground. The ground re-emits slightly different infrared radiation that is not able to pass back through the atmosphere and is trapped by gases called greenhouse gases.
Greenhouse gases	Gases that trap re-emitted infrared radiation – including carbon dioxide, methane and water vapour.
Importance of the greenhouse effect	The greenhouse effect is extremely important; without it the average global temperature would be 32 °C lower and most life could not exist.
Increased greenhouse effect	Human activities are increasing the concentration of greenhouse gases such as carbon dioxide and methane, meaning the greenhouse effect is strong and traps more heat.
Global warming	An increase in global temperatures caused by the increased greenhouse effect.
Climate change	Change in global weather patterns caused by global warming.
Correlation between carbon dioxide and temperature	In Earth's history, every time CO_2 concentrations have been high, the temperature has also been high. This makes scientists think that the current increase in CO_2 is what is increasing the temperature.
Uncertainty in the data	Scientists measurements of past temperature and CO_2 are not perfect which makes some people doubt them. However, many different sets of data say very similar things, so most scientists believe them.

C17d Climate change

Two main causes of climate change	- Carbon dioxide produced by burning fossil fuels - Methane produced by farming (especially cows) - rice paddy fields produce significant amounts of methane
Effects of climate change	- Rising average global temperature - Increased sea level from melting ice - Increased drought in some areas and flooding in others - Increase in dangerous weather
Effect of climate change on life	Living organisms are adapted to the conditions where they live. If these conditions change, they may struggle to survive. Climate change is causing many species to struggle and some to go extinct.
Ocean acidification	The carbon dioxide we produce dissolves in the oceans, lowering the pH making it harder for many sea-creatures to build their shells.
Limiting climate change	- Reduce emissions of greenhouse gases by using renewable energy and eating less meat. - Geoengineering – perhaps placing giant mirrors in space to reflect some of the sun's heat.

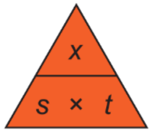
Lesson	Memorised?
C16a Hydrocarbons in crude oil and natural gas	
C16b Fractional distillation of crude oil	
C16c The alkane homologous series	
C16d Complete and incomplete combustion	
C16e Combustible fuels and pollution	
C16f Breaking down hydrocarbons	
C17a The early atmosphere	
C17b The changing atmosphere	
C17c The atmosphere today	
C17d Climate change	

CP1/SP1 Motion

1. Vectors and Scalars

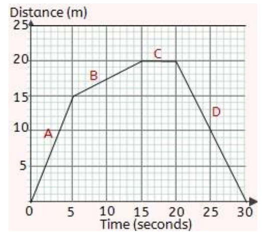
Magnitude	The size of something, such as the size of a force or the measurement of a distance.
Scalar quantity	A quantity that has a magnitude (size) only, but not a direction.
Scalar examples	Distance – 10 m Speed – 25 m/s Mass – 50 kg Energy – 300 J
Vector quantity	A quantity that has both a magnitude (size) and a direction.
Vector examples	Displacement – 10 m north Velocity – 25 m/s east Force – 30 N left Acceleration – 3 m/s^2 south Momentum – 400 N m/s right Weight – 600N down
Vector arrows	Vectors can be represented by arrows, with the length of the arrow representing the magnitude.
Displacement	The distance travelled in a particular direction.
Velocity	The speed of an object in a particular direction.

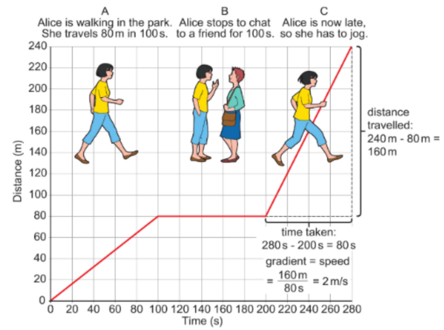
2. Speed

Speed	A measure of the distance an object travels in a given time.
Units of speed	Metres per second (m/s)
Some typical speeds	Walking – 1.4 m/s Cycling – 6 m/s Speed limit in towns – 10.5 m/s Ferry 18 m/s Motorway speed limit – 31 m/s Commuter train – 55 m/s High speed train – 90 m/s Airliner – 250 m/s
Speed – word equation	Speed = distance / time Speed (m/s) Distance (m) Time (s) 
Speed – symbol equation	v = x/t v = speed x = distance t = time
Instantaneous speed	The speed at one particular moment in a journey.
Average speed	The speed worked out from the total distance travelled divided by the total time taken for a journey. v = x/t.
Calculating distance travelled – word equation	Distance = average speed x time x = v x t Distance (m) Average speed (m/s) Time (s)
Measuring speed	Measure the distance between two points and time how long an object takes to pass, then calculate using v = x/t.
Light gates	A piece of apparatus containing an infrared beam that is transmitted from a source onto a detector. If the beam is cut, the light gate measures how long it is cut for, giving a reading for time.

3. Distance-Time Graphs

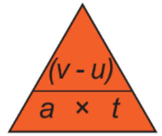
Distance-time graph	A graph showing the distance travelled against time for a moving object. Time is on the x-axis and distance on the y-axis.
Distance-time graphs – stationary	Horizontal line **C** on diagram below
Distance-time graphs – constant speed	Forwards – line sloping up **A and B** on diagram below Backwards – line sloping down **D** on diagram below
Distance-time graphs – line gradient	A measurement describing the steepness of the line on a graph. Steeper line = faster, so **A** is faster than **B** below
Calculating speed from the gradient of a distance-time graph	Speed = change in distance/ change in time =gradient gradient = change in y / change in x





D The gradient of a distance/time graph gives the speed.

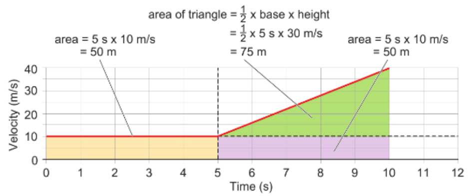
4. Acceleration

Acceleration	A measure of how quickly the velocity of something is changing. Rate of change of velocity. It is positive if an object is speeding up and negative if it is slowing down. A vector quantity.
An object accelerates when it…	- Speeds up - Slows down - Changes direction
Units of acceleration	Metres per second squared (m/s^2)
Positive and negative acceleration	Positive acceleration = speeding up Negative acceleration = slowing down
Deceleration	Slowing down, negative acceleration.
Acceleration – word equation	Acceleration = change in velocity / time Acceleration (m/s^2) Change in velocity (m/s) Time (s)
Acceleration – symbol equation	a = (v – u)/ t  a = acceleration v = final velocity u = initial velocity t = time
Linking acceleration and distance travelled	Use the equation: $v^2 - u^2 = 2ax$ to find distance $x = (v^2 - u^2) / 2a$ x = distance travelled a = acceleration v = final speed u = initial speed
Acceleration due to gravity (free fall)	10 m/s^2

5. Velocity-Time Graphs

Velocity-time graph	A graph of velocity against time for a moving object. Time is on the x-axis, velocity is on the y-axis.
Velocity-time graphs – constant speed	Horizontal line

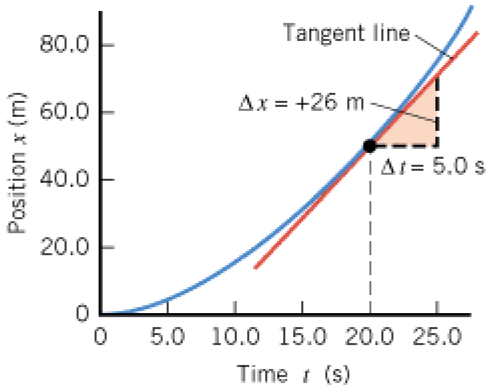
Velocity-time graphs – acceleration	Speeding up – line sloping up Slowing down – line sloping down
Velocity-time graphs – stationary	Horizontal line on the x-axis
Velocity-time graphs – line gradient	Steeper line = greater acceleration
Calculating acceleration on a velocity-time graph	Acceleration = change in velocity / change in time = gradient gradient = change in y / change in x
Calculating distance travelled from a velocity-time graph	Distance = area under the graph. Divide the graph into rectangles and triangles, find the area of each and add them together.



The total distance travelled by the object in graph D is the sum of all the areas.

total distance travelled = 50 m + 50 m + 75 m = 175 m

6. Calculating instantaneous speed (HIGHER ONLY)	
Instantaneous speed	Draw a tangent to the curve of the graph at the time you want to calculate the instantaneous speed for. Find the gradient of the tangent line by calculating the change in distance on the y axis and the change in time on the x axis. Instantaneous speed = gradient of tangent = change in distance / change in time



Lesson	Memorised?
1. Vectors and Scalars	
2. Speed	
3. Distance-Time Graphs	
4. Acceleration	
5. Velocity Time Graphs	
6. Calculating instantaneous speed (HIGHER ONLY)	

CP2/SP2 Forces and Motion

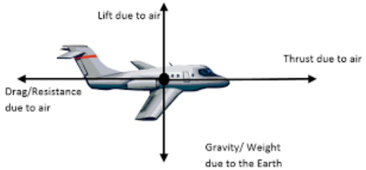
Kettering Science Academy

Lesson sequence

40. Resultant forces
41. Newton's first law
42. Mass and weight
43. Newton's second law
44. Core practical – investigating acceleration (CP12)
45. Newton's third law
46. Momentum (HT ONLY)
47. Stopping distances
48. Car safety
49. Braking distance and energy (TRIPLE ONLY)

1.Resultant forces

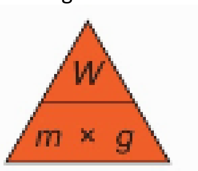
Scalar quantity	A quantity with magnitude (but no direction).
Vector quantity	A quantity with magnitude and direction.
Force arrows	Arrows can be used to represent forces: - Direction = direction of force - Length = size of force
Resultant force	The force left over when forces acting in opposite directions are cancelled out.
Calculating resultant force	Subtract the total force in one direction from the total force in the other direction.
Balanced forces	When the resultant force is zero (because forces acting in opposite directions are the same size).
Unbalanced forces	When the resultant force is non-zero (because there is more force in one direction than another).



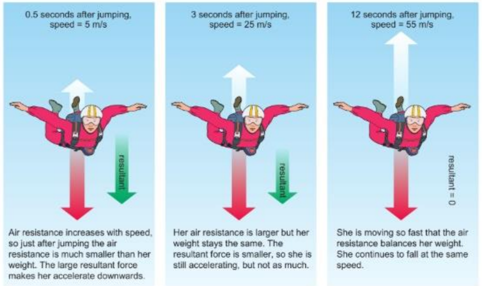
2. Newton's first law

Newton's first law of motion	An object will move at the same speed and direction unless it experiences a resultant force.
The effect of resultant forces	Resultant forces cause acceleration: speeding up, slowing down or changing direction
The effect of forces on motion	Forces make you start moving, stop moving or change direction, they are not needed to keep you moving!

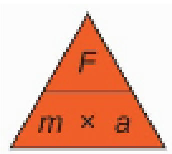
3. Mass and weight

Mass	The quantity of matter in an object is made of. Units = kilograms (kg)
Weight	A force caused by gravity pulling downward on an object. Units = newtons (N)
Force meter	An instrument for measuring forces. They usually have a spring that stretches more the greater the force applied.
Gravitational field strength	The strength of gravity, which is different on different planets. Units = newtons per kilogram (N/kg)
Gravitational field strength on Earth	10 N/kg
Calculating weight	Weight = mass x gravitational field strength W = m x g  Weight (N) Mass (kg) Gravitational field strength (N/kg)

Air resistance	A force caused by the air pushing against you as you move. Faster movement → greater air resistance.
Motion whilst falling	Falling objects accelerate until the air resistance is equal to the weight; now there is no resultant force so speed stays constant (**terminal velocity**).

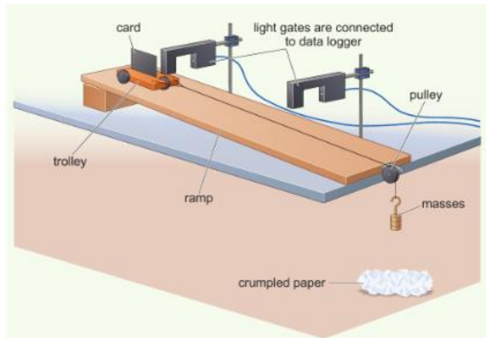


4. Newton's second law

Newton's second law of motion	Force = mass x acceleration
Acceleration is greater when…	- The force is greater - The mass is smaller
Calculating forces	Force = mass x acceleration F = m x a  Force (N) Mass (kg) Acceleration (m/s²)
Calculating acceleration	Acceleration = mass / force a = F / m Force = N Mass = kg Acceleration = m/s²

5. Core practical – investigating acceleration (CP12)

CP12 - Aim	To investigate how changing force changes acceleration.
CP12 - Setup	A trolley on a ramp with 9 x 10g masses. 10 g mass hanger attached to trolley via a string over a pulley.
CP12 – Data collection	Release the trolley, use light gates to measure the acceleration.
CP12 – Variations	Move 10 g of mass from the trolley to the mass hanger each time.
CP12 – Independent variable	The force: each 10 g mass = 0.1 N force
CP12 – Control variables	Move the 10 g masses from the trolley to the mass hanger to keep the total mass in the system the same. Raise the ramp slightly until the car only just starts to move freely to eliminate the effects of friction.
CP12 - Results	More mass pulling on the string → more force → greater acceleration.



6. Newton's third law

Newton's third law	For every action force there is an equal but opposite reaction force.
Action force	The force you push or pull with.
Reaction force	A force of the same size but opposite direction to an action force.
Action-reaction forces	If, A applies an action force to B, B applies a reaction force of same size and opposite direction to A.
Action-reaction vs balanced forces	Similarities: same sizes, opposite directions Differences: balanced forces act on one object, action-reaction act on two different objects

8. Stopping distances

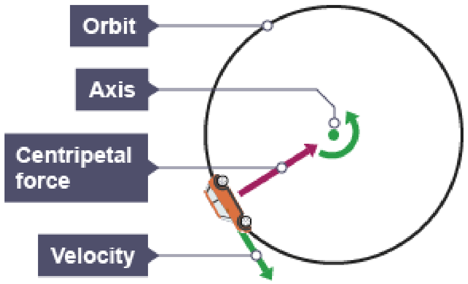
Stopping distance	The total distance travelled from when a hazard is seen to when you fully stop.
Thinking distance	The distance travelled from when a hazard is seen to when you brake.
Braking distance	The distance travelled from when you brake to when you fully stop.
Calculating stopping distance	Stopping distance = thinking distance + braking distance
Thinking distance and reaction time	Slower reactions = greater thinking distance
Thinking distance increased by…	Higher speed, tiredness, illness, drugs, distractions, old age
Braking distance increased by	Higher speed, poor brakes, poor tyres, wet/icy/gravelly road, downhill, heavier load

9. Car safety

Crash danger	Crashes involve large decelerations, creating large forces which can injure you.
How car safety features work	Increase the time a collision takes, reducing deceleration and forces.
Three car safety features	Crumple zones, (stretchy) seat belts, air bags

2. Circular motion (HIGHER AND TRIPLE ONLY)

Circular motion	Moving in a circle is a type of acceleration because you are changing velocity (your direction changes even if your speed does not).
Centripetal force	A force acting towards the centre of a circle that enables objects to move in a circle.
Sources of centripetal force	Gravity – keeps the Earth orbiting the Sun Tension – lets a bucket swing in circles on a rope Friction – keeps cars turning round a roundabout



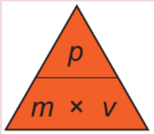
4. Inertial mass (HIGHER AND TRIPLE ONLY)

Inertial mass	The mass calculated by measuring the acceleration produced by force, using the equation m = F / a
The point of inertial mass	Inertial mass is the same as mass measured with a mass balance, but it gives us a way to measure mass where there is no gravity, such as in space.

6. Collisions (HIGHER AND TRIPLE ONLY)

Action-reaction forces in collisions	E.g. kicking a ball: the foot pushes the ball, the ball pushes back on the foot.

7. Momentum (HIGHER AND TRIPLE ONLY)

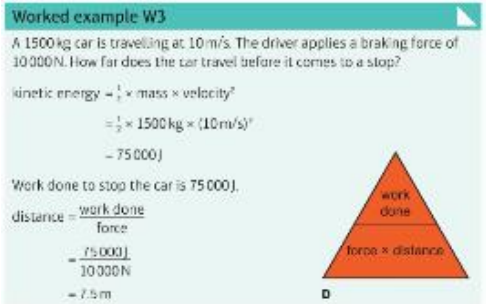
Momentum	The tendency of an object to keep moving.
Calculating momentum	Momentum = mass x velocity p = m x v  Momentum (kg m/s) Mass (kg) velocity (m/s)
Momentum and force calculations	Force = change in momentum / time F = (mv – mu)/t Force (N) Mass (kg) Velocity (m/s) Time (s)
Conservation of momentum	Total momentum before and after a collision is the same.

9. Collision forces (HIGHER AND TRIPLE ONLY)

Collision forces	Greater momentum change → greater force
Calculating collision forces	Force = change in momentum / time F = (mv – mu)/t Force (N) Mass (kg) Velocity (m/s) Time (s)

Lesson	Memorised?
1. Resultant forces	
2. Newton's first law	
3. Mass and weight	
4. Newton's second law	
5. Core practical – investigating acceleration (CP12)	
6. Newton's third law	
8. Stopping distances	
9.Car safety	
(HIGHER AND TRIPLE ONLY)	
2. Circular motion	
4. Inertial mass	
6. Collisions	
7. Momentum	
9.Collision forces	
10. (TRIPLE ONLY) Braking distance and energy	

10. Braking distance and energy (TRIPLE ONLY)	
Work done	The energy transferred by a force acting over a distance is called work done. Measured in joules (J)
Calculating work done	Work done = force x distance moved in the direction of the force  Work done (J) Force (N) distance (m)
Kinetic energy	Energy stored in a moving object Measured in joules (j)
Calculating kinetic energy	kinetic energy = $\frac{1}{2}$ × mass × $(\text{speed})^2$ Kinetic energy (J) Mass (kg) $(\text{Speed})^2$ $(\text{m/s})^2$
Estimating stopping distance using mass, braking force and speed	See worked example below. Remember that work done and energy transferred are the same.



Worked example W3

A 1500 kg car is travelling at 10 m/s. The driver applies a braking force of 10 000 N. How far does the car travel before it comes to a stop?

kinetic energy = $\frac{1}{2}$ × mass × velocity^2

= $\frac{1}{2}$ × 1500 kg × $(10\ \text{m/s})^2$

= 75 000 J

Work done to stop the car is 75 000 J.

distance = $\frac{\text{work done}}{\text{force}}$

= $\frac{75\,000\ \text{J}}{10\,000\ \text{N}}$

= 7.5 m

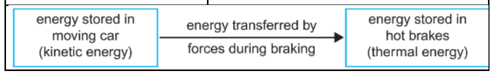
CP3 Conservation of Energy

Lesson sequence

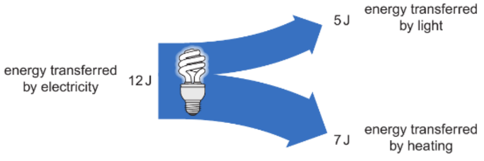
50. Energy stores and transfers
51. Energy efficiency
52. Keeping warm
53. Stored energies
54. Non-renewable energy resources
55. Renewable energy resources

1. Energy stores and transfers

Energy	The capacity to do work.
Joules	The units of energy, symbol = J
Kilojoules	1000 J, symbol = kJ
Thermal energy	Energy stored in hot objects.
Kinetic energy	Energy stored in moving objects.
Chemical energy	Energy stored in chemicals such as fuels.
Nuclear energy	Energy stored in the nucleus of atoms. Also called atomic energy.
Gravitational potential energy	Energy stored in objects based on how high they are.
Elastic potential energy	Also called strain energy. Energy stored in bent or stretched objects.
Energy stores examples	Light, thermal(heat), sound, electrical, kinetic (movement)
Law of conservation of energy	Energy cannot be created or destroyed, just transferred from one energy store to another.
Energy transfers	Say from what store the energy starts as *and* what its new store is.

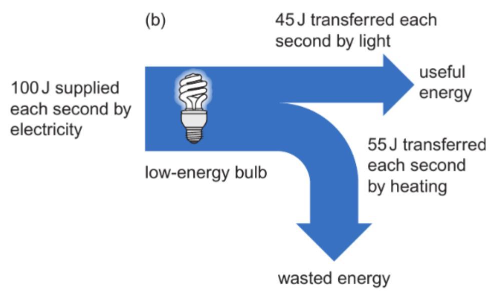


Sankey diagram	Shows energy transfers. The thickness of the arrow relates to the amount of energy.



2. Energy efficiency

Dissipation	The way energy spreads out into the surroundings, becoming less useful as it does.
Wasted energy	Energy that is transferred into stores that aren't useful.
Friction	Causes thermal energy loss as heat when two surfaces rub together.
Lubrication	Allows surfaces to move smoothly, reduces energy loss from friction.
Electrical resistance	Causes wires to heat up, wasting electrical energy.
Calculating efficiency	$\text{efficiency} = \frac{\text{(useful energy transferred by the device)}}{\text{(total energy supplied to the device)}}$ Efficiency is expressed as a decimal.
Energy efficiency numbers	Efficiency is between 0 and 1. 1 = no energy wasted 0 = all energy wasted

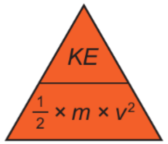


3. Keeping warm

Convection	Heat transfer caused when hot fluids (gas or liquid) rise because they are less dense.
Conduction	Heat transfer through solids caused by vibrating particles bumping into each other.
Radiation	Heat transfer by infrared radiation which heats objects up when they absorb it.
Radiation and surfaces	Infrared radiation is absorbed (taken in) and emitted (given out) easily by dull, dark surfaces. Radiation is absorbed and emitted poorly by shiny, light surfaces.
Insulation	Materials that contain lots of tiny air pockets that prevent heat loss by conduction.
Thermal conductivity	A measure of how well a material conducts heat.
Reducing the rate of energy transfer	Increase thickness of material Decrease thermal conductivity Decrease temperature difference

4. Stored energies

Gravitational field strength g	The strength of gravity. Different on different planets. On Earth g = 10 N/kg.
Calculating gravitational potential energy	$GPE = mg\Delta h$  GPE is gravitational potential energy (J) m is mass (kg) g is gravitational field strength (N/kg) Δh is height change (m)

Calculating kinetic energy	$KE = \frac{1}{2}mv^2$  KE is kinetic energy (J) m is mass (kg) v is velocity (m/s)
Calculating v from KE	$v = \sqrt{\frac{2KE}{m}}$

5. Non-renewable energy resources

Non-renewable resource	A resource that will one day run out because it is being used faster than it is being made.
Fossil fuels	Coal, oil, natural gas. All are non-renewable.
Harm from burning fossil fuels	Carbon dioxide gas is released which causes global warming. Sulfur dioxide is released which causes acid rain.
Nuclear power	Electricity generated from non-renewable nuclear fuels such as uranium.
Nuclear power pros and cons	😊 Lasts a long time, releases no carbon dioxide ☹ Produces very harmful waste, expensive to decommission, although rare, accidents are very dangerous.
Climate change	Changes that happen to global weather patterns as a result of global warming.

6. Renewable energy resources	
Renewable resource	A resource will not run out.
Wind power	Large turbines spun by the wind turn kinetic energy into electrical energy. 😊No CO_2 ☹Lots needed, ugly?, no wind no power
Solar power	Solar cells turn light energy from the Sun into electrical energy. 😊No CO_2 ☹No sun no power, need lots of space, not suitable for all countries
Tidal power	Uses kinetic energy from water movement from tides to spin turbines and produce electrical energy.
Tidal barrage	A damn built across an estuary that fills up when tide goes in. When stored water is released its kinetic energy produces electrical energy. 😊Huge amounts of energy, no CO_2 ☹Destroys important mudflat habitats
Hydroelectricity	A damn is built across a river valley, water released from the damn spins turbine and its kinetic energy produces electrical energy. 😊Lots of energy, no CO_2 ☹Destroys habitat by flooding
Biofuels	Fuels made from recently plant or animal matter, often waste, are a store of chemical energy. 😊Carbon neutral ☹Needs a lot of land, increases food prices

Carbon neutral	When burning a fuel releases the same CO_2 it absorbed when it was growing, so there is no CO_2 increase.

7. Reducing energy losses (HIGHER ONLY)	
Reducing energy losses	Increases the efficiency of a device or process, e.g. engines. This can be by reducing friction; by making sure all fuel is burned; or by using energy that would otherwise be wasted.

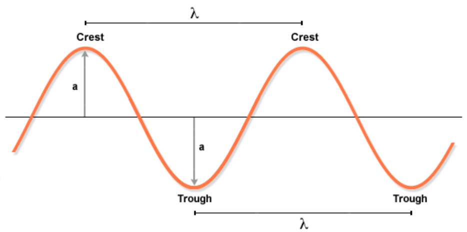
Lesson	Memorised?
1. Energy stores and transfers	
2. Energy efficiency	
3. Keeping warm	
4. Stored energies	
5. Non-renewable energy resources	
6. Renewable energy resources	
7. Reducing energy losses (HIGHER ONLY)	

P4 Waves

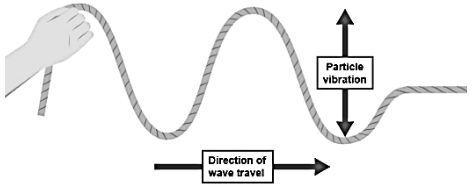
1. Describing waves

Waves	Transfer energy without transferring matter.
Oscillate	When particles vibrate backwards and forwards or up and down.
Transverse waves	Waves in which particles oscillate at right angles to the direction of energy movement. E.g., waves on the surface of the water, some seismic waves and light waves (all electromagnetic waves).
Longitudinal waves	Waves in which particles oscillate parallel to the direction of energy movement. E.g., sound waves and some seismic waves.
Medium	The material that waves travel through. Light (all electromagnetic waves) waves are the only waves that have no medium.
Seismic waves	Waves of vibrating rock caused by earthquakes.
Frequency, f	The number of waves that pass a point every second.
Hertz, Hz	The unit of frequency. 1 Hz = 1 wave per second.
Period, T	The length of time it takes for a single wave to pass.
Wavelength, λ	The distance in m from the top of one wave to the top of the next.
Amplitude, a or A	The maximum distance a particle vibrates away from its resting point,
Velocity, v	The speed of a wave in m/s.

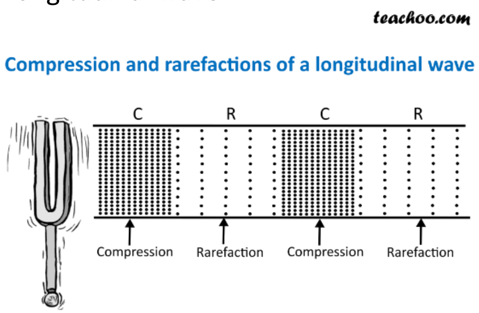
Transverse wave



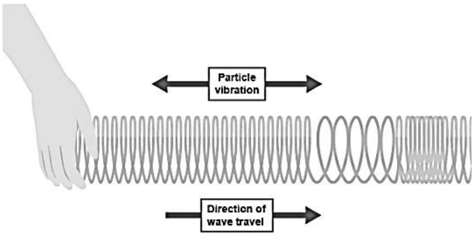
Transverse wave



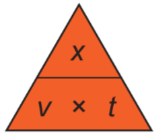
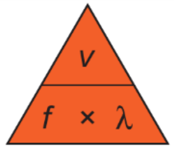
Longitudinal wave



Longitudinal wave



2. Wave speeds

Speed, distance and time	$wave\ speed\ (m/s) = \frac{distance\ (m)}{time\ (s)}$  Wave speed = v Distance = x Time = t
Speed, frequency and wavelength	$wave\ speed\ \left(\frac{m}{s}\right) = frequency\ (Hz) \times wavelength\ (m)$  Wave speed = v Frequency = f Wavelength = λ
Measuring wave speed	Time how long they take to travel a certain distance. (stopwatch) Distance between two points.(tape measure)
Changing speed	Waves travel at a different speed in a different medium. Light is slower in water than air.

3. Core practical – Investigating waves

CP4 - Aim	To measure the speed of waves in a liquid and a solid.
CP4 – Water waves 1	1. Count the number of waves in 10 s and use this to find the frequency. 2. Measure the wavelength with a ruler Wave speed = frequency x wavelength
CP4 – Water waves 2	1. Time how long a wave takes to pass two points, 0.3 m apart. Wave speed = dist / time
CP4 - Waves in a solid	1. Hit suspended metal bar with hammer and measure the frequency using an app. Measure the metal bar – double the length gives the wavelength

4. Refraction

Refraction	Bending of waves when they enter a new medium at an angle.
Interface	The boundary between two media (mediums) such as air and water.
Normal	An imaginary line drawn at 90° to where light hits an interface (boundary).
Angle of incidence	The angle between an incoming light ray and the normal.
Angle of refraction	The angle between the normal and a ray of light that has been refracted.
Travelling from air to glass or water	Light bends towards the normal
Travelling from glass or air to water	Light bends away from the normal.
Explaining refraction	Light waves slow down as they go from air to water. The 'bottom' of the wave hits the water and slows down first, causing refraction.

Lesson	Memorised?
1. Describing waves	
2. Wave speeds	
3. Core practical – Investigating waves	
4. Refraction	

P5 Light and the Electromagnetic waves

1. Electromagnetic waves

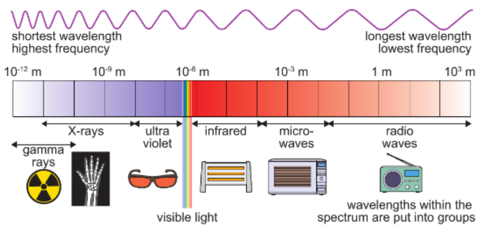
Electromagnetic waves	A group of waves that all travel at the same speed (speed of light) in a vacuum, and are all transverse.
Speed of light	300,000,000 m/s (3 x 10^8 m/s)
Frequency	The number of waves that pass a point every second. One hertz (Hz) is one wave per second.
Wavelength	The distance between a point on one wave and the same point on the next wave.
EM wave similarities	All are transverse, all travel at the speed of light.
EM wave differences	Different frequencies, different wavelengths.
Visible light	The only type of EM radiation that our eyes can detect.
Interface	The boundary between two different materials.
Refraction and wave speed	Light travels at different speeds in different materials causing it to refract when hitting the interface at an angle.
Prisms and the colour spectrum	Different wavelengths slow down by different amounts when they hit glass causing each colour to refract differently.
Infrared discovery	Light split into a spectrum. Thermometer placed on every colour plus next to red. Red was hot, next to red was hottest.

2. Core practical – Investigating refraction

Normal	A line at right angles to the interface.
Angle of incidence	Angle between the incident ray and the normal.
Angle of refraction	Angle between the refracted ray and the normal.
CP5 – Aim	To explore how changing the angle of incidence changes the angle of refraction.
CP5 - Setup	Place a glass block on a sheet of paper, point a beam of light from a ray box at it, trace around the block and draw in the light ray.
CP5 - Measurement	Use a protractor to draw a normal, then measure the angles of incidence and refraction.
CP5 - Variations	Repeat 5 times, from 5 different angles, including head-on.
CP5 - Results	The greater the angle of incidence, the greater the angle of refraction.

3. The electromagnetic spectrum

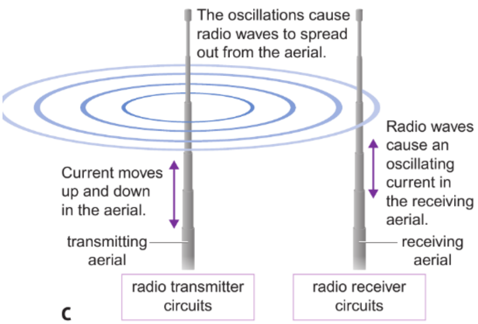
EM spectrum mnemonic	**R**ubbish **M**emories **I**nclude **V**isiting **U**r **X** **G**irlfriend
EM spectrum – lowest to highest frequency or energy	Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.
EM spectrum – lowest to highest wavelength	Gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, radio waves.
EM spectrum	The full range of types of EM waves.
EM Radiation and the atmosphere	Some EM radiation (visible light, radio waves) passes through the atmosphere, most is absorbed.
Space telescopes	For radiation absorbed by the atmosphere, a telescope must be placed in space.



Electromagnetic spectrum

4. Using the long wavelengths

Visible light uses	Illumination, photography
Infrared uses	Short-range communications (TV remotes), fibre optics, cooking (grills and toasters), security cameras, thermal images.
Microwave uses	Microwave ovens, mobile phone and satellite communications.
Radio wave uses	Radio and TV signals, communications between controllers and spacecraft, satellite communications.
Producing radio waves	Oscillating electricity in a metal rod produces radio waves.
Receiving radio waves	Radio waves absorbed by a metal rod cause electrical oscillations.



Producing radio waves

5. Using the short wavelengths

Fluorescence	Absorbing ultraviolet and re-emitting it as visible light.
Ultraviolet uses	Security marking, fluorescent lamps, detecting forged bank notes and disinfecting water.
X-ray uses	Observing the internal structure of objects, airport security scanners and medical X-rays.
Gamma ray uses	Sterilising food and medical equipment, and the detection of cancer and its treatment.

6. EM radiation dangers

Infrared dangers	Surface heating causing skin burns.
Microwave dangers	Absorbed by water causing it to heat up → internal heating of body cells.
Ionisation	High-energy radiation causes ions to form in our cells, damaging DNA and causing cancer.
Ultraviolet dangers	Damage to surface cells and eyes leading to skin cancer and eye conditions.
X-ray dangers	Cancer, mutation or damage to cells in the body.
Gamma ray dangers	Cancer, mutation or damage to cells in the body.

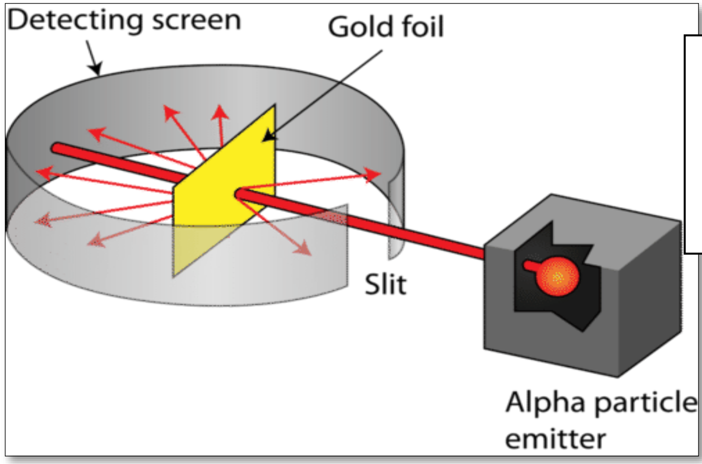
Lesson	Memorised?
1. Electromagnetic waves	
2. Core practical – Investigating refraction	
3. The electromagnetic spectrum	
4. Using the long wavelengths	
5. Using the short wavelengths	
6. EM radiation dangers	

CP6: Radioactivity

Lesson sequence

56. Atomic structure
57. Subatomic particles
58. Electron orbits
59. Radiation from unstable atoms
60. Nuclear reactions
61. Half-life
62. Background radiation
63. Dangers of radioactivity

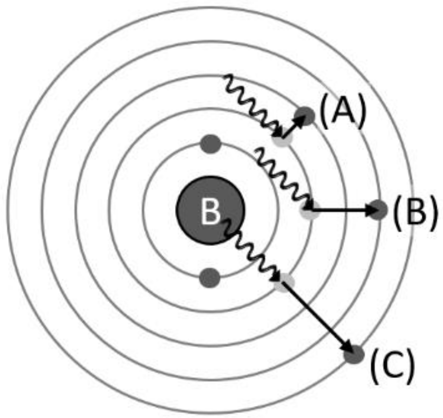
1. Atomic structure	
***Atom**	Smallest particle of an element.
****Size of atoms**	2.5 x10^{-10} m in diameter
***Element**	Pure substance made of a single type of atom.
****Plum-pudding model**	Atoms as a sphere of positively charged matter with negative electrons scattered throughout it. Rutherford's experiment disproves this
****Rutherford's experiment**	Fired alpha particles at very thin gold leaf and used a special screen to record where they went.
****Rutherford's results**	Most alpha particles went straight through, some scattered (changed path).
****Rutherford's explanation**	See diagram. Most α went through the empty space. The scattered ones must have bounced off the **nucleus**
Rutherford's model	A positive **nucleus** with electrons going round it
Nucleus	The central part of an atom; very small and dense, positively charged. **Rutherford's experiment** proves its existence. (Made of protons and neutrons)
Bohr's model	Same as Rutherford's, but the electrons can only be in certain **orbits / shells**



Rutherford's alpha-scattering experiment proves the existence of the nucleus

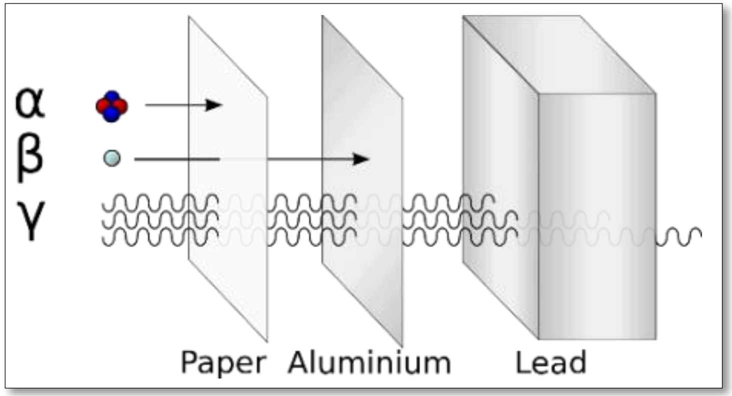
2. Subatomic particles	
***Subatomic particle**	Any particle smaller than atoms: protons, neutrons and electrons.
***Protons**	+1 charge, mass = 1, located in the nucleus
***Neutrons**	0 charge, mass = 1, located in the nucleus
***Electrons**	-1 charge, mass = 1/1835, located around nucleus in shells
****Relative mass**	Not the actual mass because no units. Protons and neutrons have same relative mass: their mass is 1.
***Nucleons**	The particles in the nucleus: protons and neutrons.
***Determining the element**	The number of protons determines which element an atom is.
***Atomic number**	The number of protons in an atom.
***Mass number**	The number of nucleons (protons and neutrons) in an atom.
***Number of neutrons**	Mass number – atomic number
****Isotopes**	Versions of an element with the same number of protons, but different number of neutrons.
****Naming isotopes**	Carbon-13, or ^{13}C, where 13 is the mass number

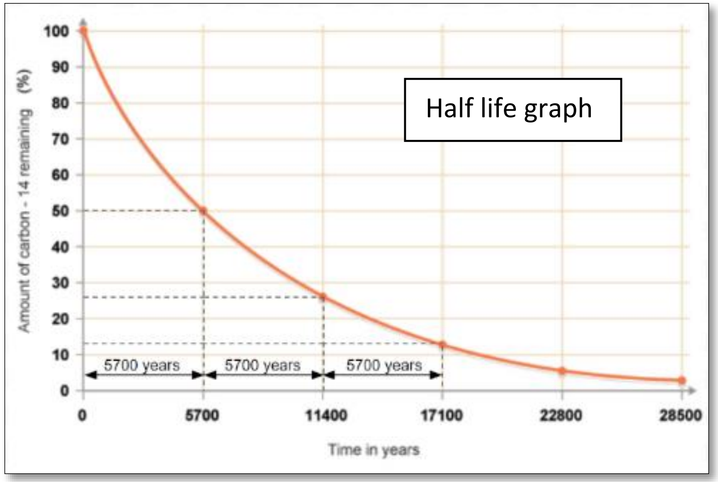
3. Electron orbits	
****Orbits**	The shells of electrons around an atom.
****Orbits and energy**	Higher orbit = higher energy
****Excited electrons**	When an electron has absorbed energy and jumped to a higher orbit.
*****How to excite electrons**	- When atoms absorb light - When electricity is passed through gases - Strongly heating a material
*****Absorbing light**	When electron absorbs light and jumps up to a higher shell.
*****Emitting light**	When electrons drop down to a lower shell and emit light.
*****Emission spectrum**	Pattern of bands of light at specific wavelengths caused by exciting a gaseous element with electricity.
*****Absorption spectrum**	Pattern of dark band in a 'rainbow' spectrum caused by a gas absorbing some of the light
*****Forming ions**	When an electron is given so much energy it leaves the atom entirely creating a positive ion.
****Ionising radiation**	Radiation that causes ionisation: (high energy) UV, x-rays, gamma rays.



Bohr's model of the atom has electrons in 'shells' or 'orbits', around the nucleus

The electrons can be 'excited' to higher shells by absorbing energy, eg from light





8. Dangers of radioactivity	
***Mutations**	DNA damage caused by ionising radiation, can lead to cancer.
****Repairing damage**	Cells contain proteins that can repair DNA damage as long as the radiation dose is low enough.
****Minimising radiation risk**	- Wear protective clothing - Handle with tongs - Don't point at people - Limit time - Use protective shielding - Wear dosimeter badges
****Nuclear power risks**	There is a small chance of accidents causing radioactive sources to escape
****Irradiation**	Exposure to radiation, stops when the source of radiation is removed.
****Contamination**	When particles of radioactive substances are on or in the body.
****Risks in perspective**	Using radioactivity carries serious risks, but so do many other things, so it is safe to use as long as it is treated with caution.

4. Radiation from unstable atoms	
***Unstable atom**	An atom whose nucleus contains too much energy becomes unstable.
***Decay**	When an unstable atom releases its excess energy; this releases ionising radiation.
***Alpha radiation**	Made of alpha particles: two protons and two neutrons. Symbol: α or ${}^{4}_{2}He$. Blocked by air/paper
***Beta-minus radiation**	**Beta-** particles are fast-moving **electrons**. Symbol: β^- or ${}^{0}_{-1}e$. Blocked by aluminium
***Beta-plus radiation**	**Beta+** particles are **positrons**: particles with same mass as electrons but a positive charge. Symbol: β^+ or ${}^{0}_{1}e$.
***Gamma radiation**	electromagnetic radiation. Extremely short wavelength / high frequency / high energy Symbol: γ. Blocked by lead/concrete
***Neutron radiation**	Fast-moving neutrons. Symbol: n.
***Ionising power**	Alpha is most ionising, gamma least.
***Penetrating power**	Gamma is most penetrating, alpha least

5. Nuclear reactions	
****Alpha decay**	Atomic number decreases by two, mass number decreases by four.
****Beta-decay**	Atomic number increases by one, mass number stays the same.
****Beta+ decay**	Atomic number decreases by one, mass number stays the same.
****Gamma decay**	Atomic number and mass number unchanged.
****Neutron decay**	Atomic number stays the same, mass number decreases by one.

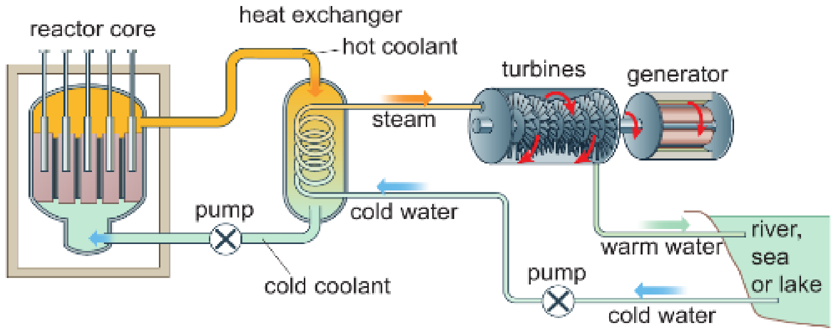
6. Half-life	
***Half-life**	The time taken for half of the undecayed atoms in a sample to decay.
Stability, half-life and activity of isotopes: Low stability = short half-life = high activity High stability = long half-life = low activity	
***Becquerels, Bq**	The unit of radioactivity: 1 Bq = one decay per second.
****Half-life graph**	x-axis = time, y-axis = radioactivity. The line curves downwards but never touches the x-axis.

7. Background radiation	
***Background radiation**	Low levels of ionising radiation that we are constantly exposed to; mainly natural causes.
***Radon gas**	The biggest source of background radiation: a radioactive gas produced by some rocks in the ground
***Other natural sources**	Background radiation also comes from food and space (cosmic rays)
***Artificial sources**	Hospitals, nuclear industry
****Geiger-Müller (GM) tube**	Used to measure radioactivity, produce a click each time radiation passes through it.
****Count-rate**	The number of time a GM tube detects radiation each second.
****Measuring background radiation**	Use a GM tube to take several readings and then calculate the average (mean).
****Corrected count rate**	Measure the source, subtract the background radiation.
***Dosimeter**	A badge that changes colour in response to radiation exposure.
***Dose**	The amount of radiation received by a person.

SP6: Radioactivity – triple only content

Radioactivity in medicine	
Tracer	A radioisotope deliberately put into the body, often attached to glucose molecules in the blood
Gamma camera	A gamma ray detector which detects where tracers are in the body, to help diagnose health problems
Tumour	A cancerous growth. Absorbs a lot of glucose so the tracer will be concentrated in a tumour
PET Scanner	Positron emission tomography. Produces a detailed 3D image of the inside of the body
	A positron emitting tracer is put into the bloodstream
	Positrons annihilate with electrons, producing gamma rays
	Gamma rays are detected outside the body, showing where the tracer has been concentrated.
Radiotherapy	Using radiation to kill cancer cells
Internal radiotherapy	A radioisotope (beta emitter) is put inside the body, near a tumour, to kill it.
External radiotherapy	Beams of gamma rays are directed at a tumour from outside the body, to kills it

Nuclear Fission	
Nuclear Fission	When a nucleus splits into two or more daughter nuclei.
Daughter nuclei	The nuclei created when a large nucleus splits.
U-235	The isotope used in power stations: when it splits, it releases a large amount of energy and 3 neutrons.
Chain reaction	When the neutrons from one fission event trigger more fission events.
Uncontrolled chain reaction	If 3 neutrons split 3 more U-235 nuclei, 9 neutrons are released. These can cause 9 more fission events, these cause 27 more … the chain reaction releases a huge amount of energy very rapidly, leading to an explosion (nuclear bomb)
Controlled chain reaction	When neutrons are absorbed, the chain reaction can continue without an explosion. Used in nuclear reactor
Nuclear reactor	Fission of U-235 releases energy through a controlled chain reaction
Control rod	Absorbs neutrons to slow down the chain reaction (boron)
Moderator	Slows down the neutrons to enable the chain reaction (graphite or water)
Problems	Radioactive waste is produced, especially when the reactor is decommissioned at the end of its life
Benefits	A reliable source of electricity, with no CO_2 to damage the atmosphere



D Radioactive fuels are used to generate electricity in nuclear power stations.

Nuclear Fusion	
The Sun	This process is how the Sun releases light and energy
Nuclear Fusion	When two small nuclei (eg hydrogen) fuse to make one nucleus (eg Helium).
Temperature and pressure	High temperature and pressure are required to overcome the electrostatic repulsion between the nuclei, and fuse them together
Electrostatic repulsion	The force which repels like charges (eg two nuclei, which are both positively charged)
Problems	Nuclear fusion is not yet useful as a power source. It is too expensive, and cannot yet produce more energy than it uses.
Benefits	Very cheap 'fuel' – hydrogen from water. No harmful gases produced, eg no CO_2 to damage the atmosphere.