

GCSE

SCIENCE

Knowledge Organisers

Combined Foundation
Combined Higher
Separate Science · Triple Higher

THINK. GROW. CARE.



THIS BOOK BELONGS TO

Make it yours.

Name

Tutor group

Science teacher

My course letter

START HERE

Course and exams	3
Understand memory	4
Retrieve, space, interleave	5–8
Try a practical strategy	6, 9–10
Support at home	11
Plan your reviews	12
Track your progress	13

A few focused minutes. An honest check. A return visit.
Keep making the knowledge yours.

Make your revision count.

A welcome from Mr Rule

Dear students, parents and carers,

Year 11 is a busy time. You may be attending revision sessions, reading revision guides, highlighting pages, copying notes or making cue cards. These activities can help you understand ideas, organise information or improve your examination technique.

However, there is an important danger: they can make knowledge feel familiar without making it retrievable.

When your teacher is explaining something, or an answer is visible on the page, you may think, "Yes, I know this." But recognising knowledge in front of you is not the same as retrieving it when it is not.

In an examination, your notes, revision guide and teacher will not be there to prompt you. You will need to retrieve what you have learned from your long-term memory.

Simply reading, highlighting or copying does not reliably make knowledge retrievable. Even making excellent cue cards creates a revision resource; it does not necessarily mean you have learned what is written on them.

Your teachers have selected the key information you need and organised it into these knowledge organisers. You do not need to spend hours reproducing them. Use your time to learn the knowledge they contain.

Follow the Look, Cover, Write, Check guidance on page 6: read and understand a small section, cover the answers, write what you can recall, then check and correct it. Practise this regularly.

It is perfectly natural not to remember everything on your first attempt. Some struggle is a normal part of learning; it shows you what to practise next. Ask for help if an idea does not make sense.

Learning research supports revisiting knowledge with gaps between attempts. Plan four or five reviews of each small set on different days as a starting routine, using the revision plan on page 12. Some knowledge needs more practice: check, correct and keep returning over time.

Use the red, amber and green tracker on page 13 to evaluate your topics. Focus first on your red topics, where recall is hardest. Revisit amber topics too, and check green ones after a longer gap.

Mr Rule | Headteacher

When you put this booklet aside, can you still remember what was on the page?

That is the difference between knowledge that feels familiar and knowledge that you can use in your examinations.

Find your way.

Use the printed page numbers to find a unit, choose a small set and start revising.

B01 Cell biology	14	C03 Quantitative chemistry	52	P02 Electricity	74
B02 Organisation	19	C04 Chemical changes	54	P03 Particle model of matter	78
B03 Infection and response	24	C05 Energy changes	58	P04 Atomic structure and radiation	80
B04 Bioenergetics	27	C06 Rate and extent of chemical change	60	P05 Forces	83
B05 Homeostasis and response	29	C07 Organic chemistry	62	P06 Waves	88
B06 Inheritance, variation and evolution	35	C08 Chemical analysis	66	P07 Magnetism and electromagnetism	94
B07 Ecology	40	C09 Chemistry of the atmosphere	68	P08 Space physics	97
C01 Atomic structure and the periodic table	44	C10 Using resources	69	S00 Working scientifically and maths	99
C02 Bonding, structure and properties	47	P01 Energy	72		

LEARNING GUIDE

Welcome 1 · Course and exams 3 · Memory 4
 Retrieval 5 · Look, Cover, Write, Check 6 · Spacing 7
 Interleaving 8 · Blank-page recall 9 · Focus 10
 Parents 11 · Revision plan 12 · Unit review tracker 13

REFERENCE

Acronyms and reminders 101
 Formulae 102
 Periodic table 108
 Required practicals 109
 AQA sources 110
 Learning research 111

Your course. Your exams.

AQA specifications say what can be assessed. Use your course letter, this overview and the topic list on page 2.

F Combined Foundation

AQA 8464 · worth 2 GCSEs

6 written papers in total

1 hour 15 minutes each

70 marks per paper

Each paper: one-sixth of the award (16.7%).

Grades 1–1 to 5–5.

H Combined Higher

AQA 8464 · worth 2 GCSEs

6 written papers in total

1 hour 15 minutes each

70 marks per paper

Each paper: one-sixth of the award (16.7%).

Grades 4–4 to 9–9; 4–3 if just below 4–4.

T Separate / Triple Higher

3 GCSEs: Biology 8461, Chemistry 8462, Physics 8463

2 papers per subject: 6 total

1 hour 45 minutes each

100 marks per paper

Each paper: 50% of its subject.

Grades 4–9; 3 if just below 4.

TWO PAPERS IN EACH SCIENCE

SUBJECT	PAPER 1 — BOOK UNITS	PAPER 2 — BOOK UNITS
Biology	B01–B04	B05–B07
Chemistry	C01–C05	C06–C10
Physics	P01–P04	P05–P07; Triple also P08 Space physics

Combined gives one paired grade across all three sciences; Triple gives a separate grade in each. Assessment is by final written exams. Expect multiple choice, short answers, calculations and longer explanations. Practical skills are tested in the written papers.

Paper 2 can draw on earlier foundations. Bring a scientific calculator, ruler, black pen and pencil. Use your personal exam timetable for dates and follow the paper instructions and your teacher's guidance about the equation sheet.

AQA specifications:

Combined 8464

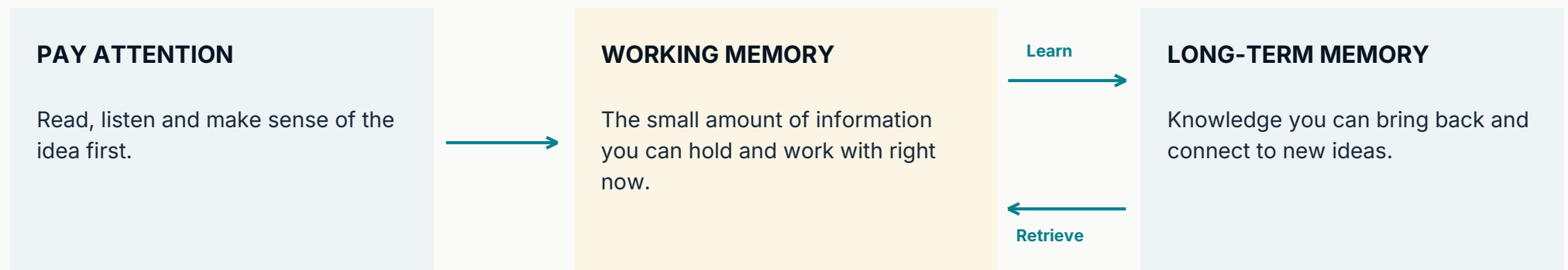
Biology 8461

Chemistry 8462

Physics 8463

Make room for bigger thinking.

Understanding, retrieval and spaced returns help you build knowledge you can use.



Retrieval helps strengthen long-term memory.

Hide the answer and bring it to mind. Check and correct your attempt, then return on another day. This is part of learning, not just a way to test whether you already know it.

Keep the load manageable.

Choose a small set of related items. Understand them, then use Look, Cover, Write, Check. A gap tells you what to practise next.

Knowledge frees room for thinking.

When facts are secure, you can give more attention to explaining, connecting ideas and choosing an approach.

You cannot join the dots until you have the dots.

Build accurate knowledge through retrieval, feedback and spaced returns, then practise using it in new questions.

Research: see the learning research references at the end of this book.

Make your revision stick.

Retrieval practice means bringing knowledge to mind before checking. It is one of the most effective ways to build lasting learning.

HIGHLY EFFECTIVE

Retrieval practice

Cover, write and check; blank-page recall; a friend quizzing you with the answers hidden.

Trying to remember, checking and correcting strengthens later recall. Repeat after gaps to help knowledge last.

LESS EFFECTIVE ON THEIR OWN

Rereading, highlighting and copying

These can help you understand or organise a topic, but looking at an answer can make it feel familiar without showing that you can recall it.

Use them to get ready. Then close or cover the material and test yourself.

This book is built for retrieval.

The prompt-and-answer tables let you cover one column, recall the missing information, then uncover it to check. Turn each row into a question for yourself.

CHOOSE

A few taught items

RECALL

Answer from memory

CHECK

Correct the gaps

RETURN

Try again after a gap

Remember it. Understand it. Use it.

Build on recall by explaining why, making connections and practising varied questions.

Look. Cover. Write. Check.

A plain sheet of paper turns the organiser into a quiz. Write your answers in an exercise book or on a whiteboard.

PROMPT	ANSWER
Diffusion	PLAIN PAPER Answers hidden. Now retrieve them.
Osmosis	
Active transport	

For diagram items, cover the picture or labels and redraw the idea on separate paper.

- ① **LOOK: read and understand**
Choose a few related rows. Ask about anything that does not make sense.
- ② **COVER: hide the answer**
Leave the prompt visible. Keep the answer out of sight.
- ③ **WRITE: retrieve from memory**
Write or draw the answer without peeking. Commit to your attempt.
- ④ **CHECK: correct precisely**
Compare with the organiser. Correct errors and missing details in another colour. Retry after a gap.

Check meaning, not just a tick.

Accurate scientific vocabulary, conditions and diagrams matter. Use the organiser for the complete answer, then test again later without looking.

Come back before it fades.

One study session is not a reliable route to lasting learning. Return on different days and retrieve again.

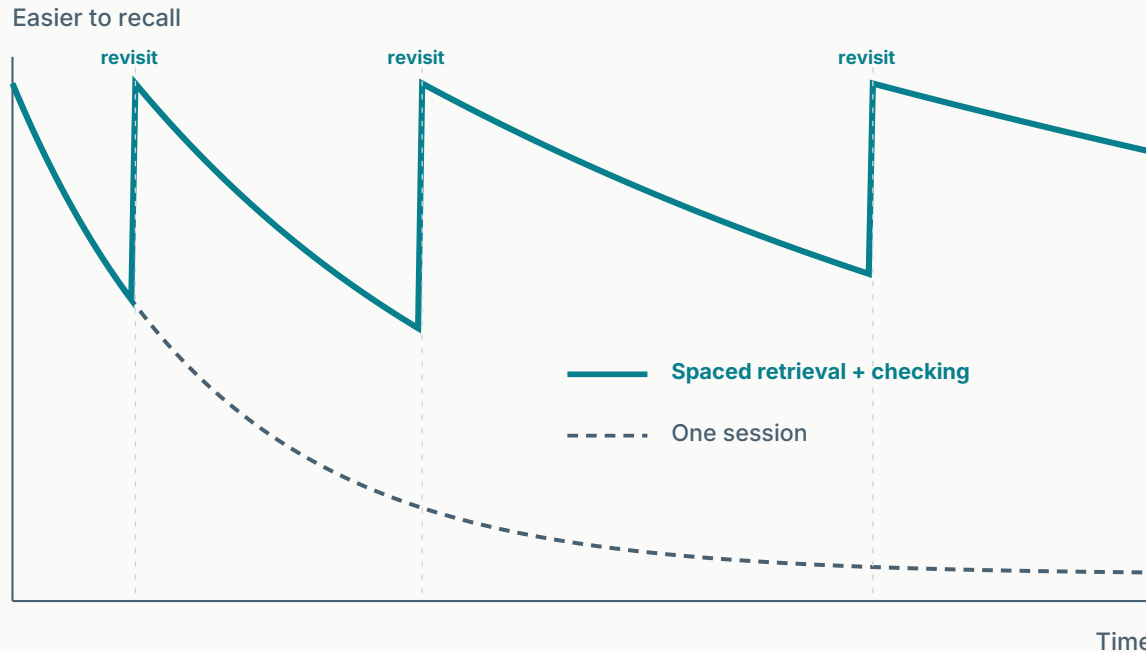


Illustration only: the curves show an idea, not measured scores or a fixed prediction for your memory.

A starting plan

Plan at least 3–5 meaningful, spaced retrieval sessions as a starting routine. Then return again.

Meaningful means: attempt with the answer hidden, check, correct and retry after a gap. Adapt the next gap to what you can recall.

Use your teacher's timetable and the date of your assessment to plan reviews.

A practical starting routine, not a scientific threshold.

Three to five sessions do not guarantee learning. Return again and adapt: revisit weak answers sooner; check secure knowledge after longer gaps.

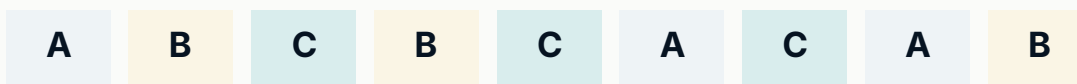
Mix questions. Choose what you know.

Interleaving means alternating between related topics or question types, instead of finishing all of one before another.

BLOCKED



MIXED

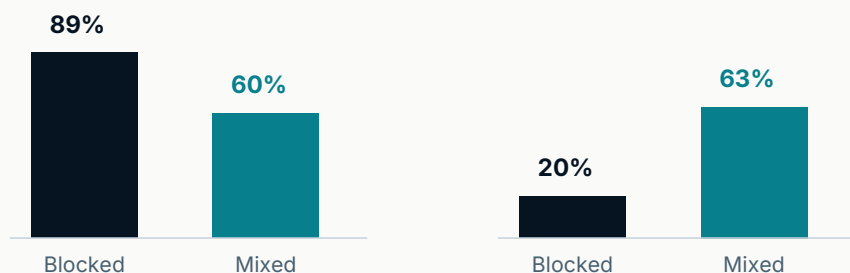


A, B and C = small sets from three related tables you have already learned.

Easier now does not always mean stronger later.

DURING PRACTICE

TEST ONE WEEK LATER



University students solving maths problems: average accuracy. This study compared practice with a later test; these are not predicted GCSE scores.

Try it with this booklet.

Choose a few items from table A. Cover, recall and check. Move to table B, then C. Return to A with the answers hidden, and vary the order next time.

Do not just reread the same table repeatedly. Mixing means you have to recognise which knowledge fits each prompt. Start with taught material and keep the sets small.

A: diffusion · B: osmosis · C: active transport

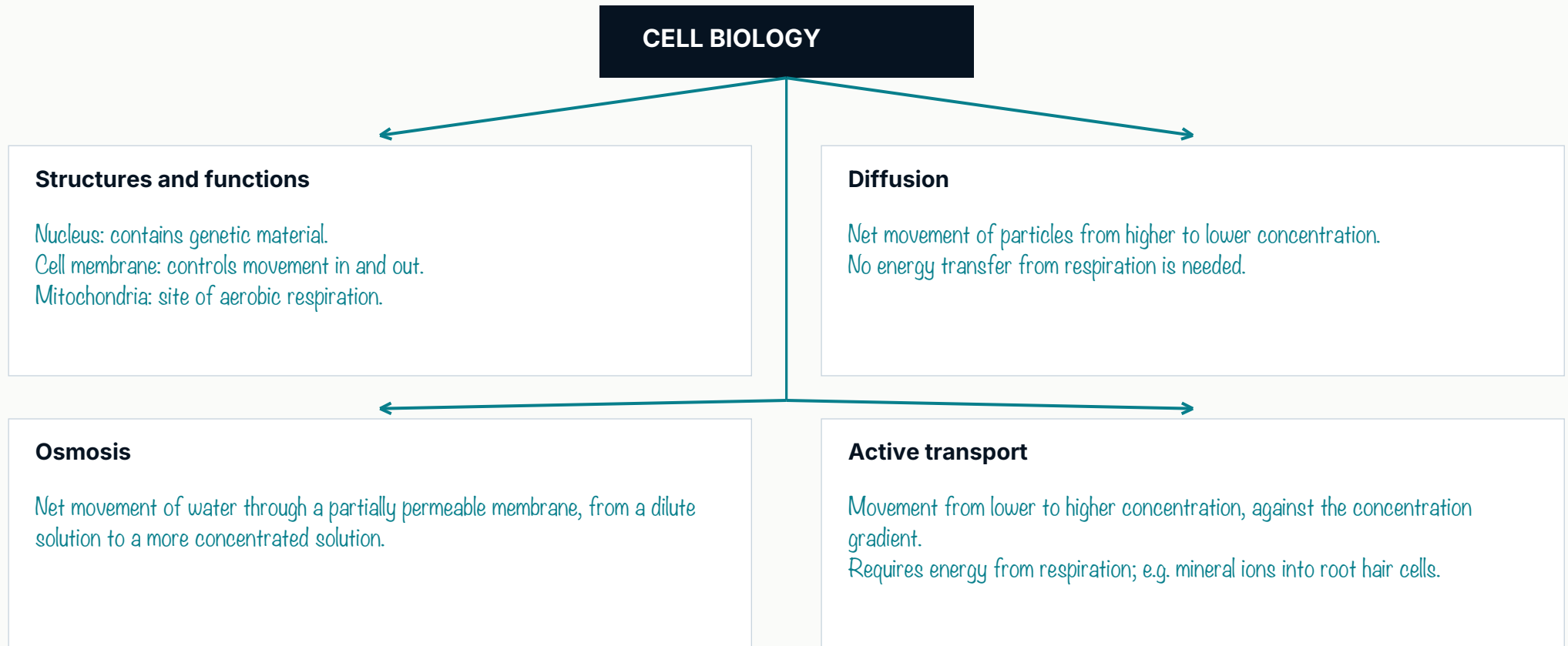
Mix within a session; space your returns across days.

A → B → C → A is mixing. Coming back tomorrow and next week is spacing. Keep both in your revision plan.

Rohrer & Taylor (2007), Experiment 2, Figure 4. DOI: 10.1007/s11251-007-9015-8

Start with a blank page.

Put the organiser away. Recall the detail: definitions, facts, quotations, formulae and labelled sketches.



Go beyond the headings. Then check the detail.

Add precise facts beneath each branch. Uncover the organiser, correct gaps in another colour, then retrieve the missing details again after a gap.

A worked model of the level of detail to aim for, not a complete list of everything in this topic.

Make starting feel manageable.

Choose a short, specific task and protect time for it. A timer can help you organise the session.

2 min

CHOOSE

Pick your topic and a small set of items.

12 min

RETRIEVE

Cover, quiz, write or draw without looking.

4 min

CHECK

Correct gaps and practise a hard item.

2 min

PLAN

Record the next review and pack away.

Pomodoro is a timing tool.

You might try 25 minutes of focused work followed by a 5-minute break. Or begin with 10 minutes. The interval is adjustable; the learning comes from what you do during it.

Build a routine you can keep.

Have the book, paper and equipment ready. Put your phone away. Take a break and protect time for rest. Follow your teacher's homework priorities rather than adding an unmanageable workload.

A useful daily habit starts small.

"I will retrieve six cell-biology facts after tea" is easier to start than "I will revise Science". Daily contact can involve different topics.

You do not need to be a subject expert.

Parents, carers and study partners can help by making practice calm, regular and easy to start.

A five-minute quiz

Agree a few rows and keep the answers where only you can see them. Read the prompt. Give thinking time. Ask the student to explain or draw. Compare the answer with the book.

Helpful things to say

"What do you remember before we look?"
"Which part is missing?"
"How could you explain that?"
"When will you come back to it?"

Respond to gaps calmly.

Let the student try before offering a clue. If needed, read the relevant line together, cover it and try a smaller question. Praise the correction and the habit of returning to it.

Help make a workable routine.

Build a realistic revision plan together. Choose small topic or item sets, schedule return dates and protect manageable study time. Fit it around lessons, homework and rest. Quiz kindly with answers hidden.

Confidence can follow practice.

Forgetting during a quiz does not mean the session has failed. Finding a gap and learning how to repair it is useful progress.

Make a rolling revision plan.

Begin with material already taught and understood. Keep each set small; build a routine you can repeat.

EACH STUDY DAY	CHOOSE A SMALL SET	RETRIEVE, THEN CHECK
New / taught set	A few understood rows, when ready	Look, Cover, Write, Check
Yesterday's set	Items introduced on the previous day	Cover, write and check
Last week's set	Items due from about seven days ago	Blank-page recall
An older set	Items due from two to four weeks ago	Blank-page recall

Schedule every new set's returns.

Example: day 0 → 1 → 3 → 7 → 14 → 28.

Day 0 is the first session. These are elapsed days, not weekdays.

Write the actual future dates beside the item codes.

Keep the plan realistic and flexible.

Use short attempts from each set due today. Hide answers, check and correct. Bring weak sets back sooner. A missed day means reschedule; it does not mean start everything again.

A starting schedule, not a universal optimum.

Plan several future returns for every new set, then adapt to recall. Only add new material that is taught and understood; protect time for homework, rest and later reviews.

See your progress. Choose your next focus.

Use recall attempts, assessment results and teacher feedback to rate each unit. Rate only the material for your course letter.

R / RED

Need help or cannot recall yet.

A / AMBER

Some secure; gaps remain.

G / GREEN

Recall accurately after a gap.

Date each review. Colour each box or write R, A or G. Leave unstudied units blank.

UNIT / TOPIC	PAGE	1	2	3	4	5	6	7	8	9	10
REVIEW DATE (day / month)		___/___	___/___	___/___	___/___	___/___	___/___	___/___	___/___	___/___	___/___
B01 Cell biology	14										
B02 Organisation	19										
B03 Infection and response	24										
B04 Bioenergetics	27										
B05 Homeostasis and response	29										
B06 Inheritance, variation and evolution	35										
B07 Ecology	40										
C01 Atomic structure and the periodic table	44										
C02 Bonding, structure and properties	47										
C03 Quantitative chemistry	52										
C04 Chemical changes	54										
C05 Energy changes	58										
C06 Rate and extent of chemical change	60										
C07 Organic chemistry	62										
C08 Chemical analysis	66										
C09 Chemistry of the atmosphere	68										
C10 Using resources	69										
P01 Energy	72										
P02 Electricity	74										
P03 Particle model of matter	78										
P04 Atomic structure and radiation	80										
P05 Forces	83										
P06 Waves	88										
P07 Magnetism and electromagnetism	94										
P08 Space physics	97										
S00 Working scientifically and maths	99										

Start with red and amber items; note their codes in your revision plan (page 12). Recheck green units after a gap.

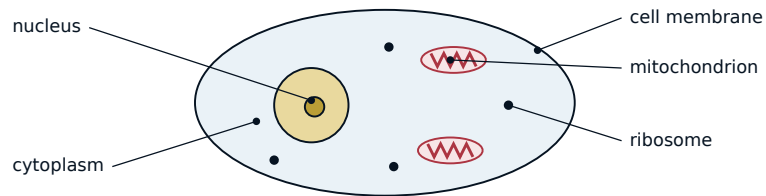
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Cell structures

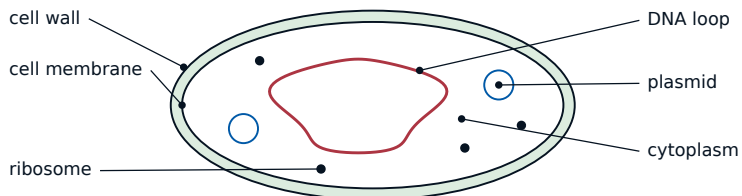
B01.01 Eukaryotic cell (F H T)

A cell whose genetic material is enclosed in a nucleus; animal and plant cells are eukaryotic.



B01.02 Prokaryotic cell (F H T)

A smaller cell without a nucleus. Bacterial DNA is a single loop in the cytoplasm; extra DNA rings called plasmids may also occur.



DNA is not enclosed by a nucleus

B01.03 (F H T) Contains genetic material and controls cell activities.

Nucleus

B01.04 (F H T) The cell material where many enzyme-controlled reactions occur.

Cytoplasm

B01.05 (F H T) Controls the movement of substances into and out of the cell.

Cell membrane

B01.06 (F H T) The site of most reactions of aerobic respiration.

Mitochondrion

B01.07 (F H T) The site of protein synthesis.

Ribosome

B01.08 (F H T) The cellulose layer outside a plant or algal cell membrane that strengthens and supports the cell.

Cell wall

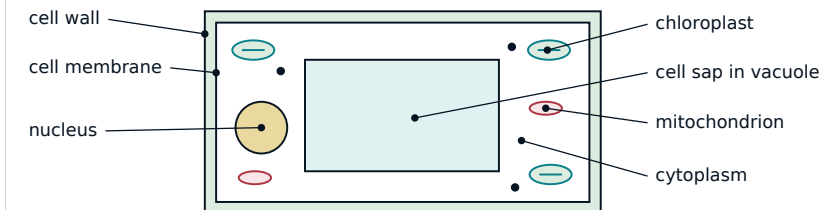
Cell structures

B01.09 (F H T) Contains chlorophyll, which absorbs light for photosynthesis.

Chloroplast

B01.10 (F H T) Permanent vacuole

Contains cell sap; helps maintain pressure against the plant cell wall.



Specialisation and microscopy

B01.11 (F H T) Differentiation The process by which a cell develops specialised structures suited to its function. Most animal cells differentiate early; many plant cells can do so throughout life.

B01.12 (F H T) Sperm cell adaptations

A tail for movement; many mitochondria for respiration; enzymes in the head help it enter an egg.



B01.R01 (F H T) Red blood cell adaptations Carries oxygen using haemoglobin. Its biconcave shape gives a large surface area for rapid diffusion. No nucleus leaves more space for haemoglobin.

B01.R02 (F H T) Root hair cell adaptations Absorbs water and mineral ions from soil. A long hair gives a large surface area. Water enters by osmosis; mineral ions can enter by active transport, using energy from respiration.

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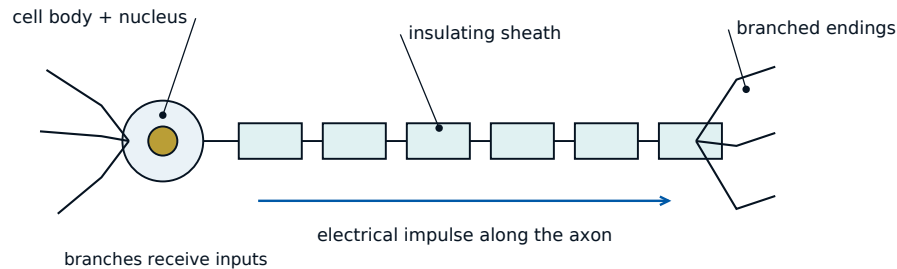
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Specialisation and microscopy

B01.13 Nerve cell adaptations

(F) (H) (T)

A long fibre carries impulses over distance; branched endings connect with other cells.



B01.14 Muscle cell adaptations

(F) (H) (T)

Contractile structures shorten the cell; many mitochondria supply energy through respiration.

B01.15 Plant specialisations

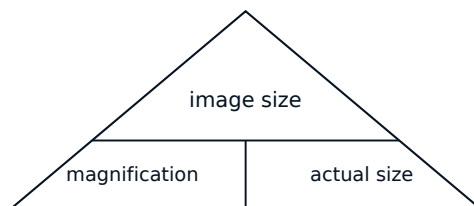
(F) (H) (T)

Root hair, xylem and phloem structure-function facts have their home in B02, Plant transport.

B01.16 Magnification

(F) (H) (T)

Image size ÷ actual size. Use the same length units for both measurements.



Use the equation and check units.

Rearrangement reminder

image size = magnification × actual size. Divide the top quantity by one lower quantity to find the other. Use the stated units.

B01.17 Resolution

(F) (H) (T)

The ability to distinguish two close points as separate. Greater magnification alone does not guarantee more detail.

B01.18 Electron microscope

(F) (H) (T)

Has greater magnification and resolving power than a light microscope, revealing smaller sub-cellular structures.

B01.19 Cell-size conversions

(F) (H) (T)

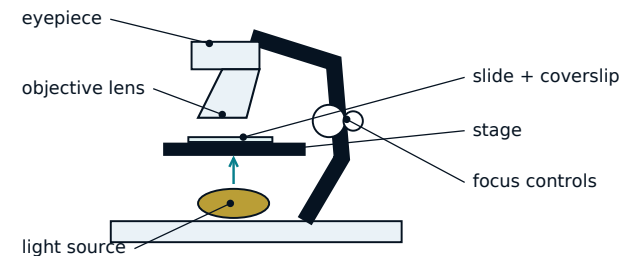
1 mm = 1000 μm; 1 μm = 1000 nm. A factor of ten is one order of magnitude.

Specialisation and microscopy

B01.20 RP Com 01 / Bio 01: focusing a microscope

(F) (H) (T)

Place a thin specimen on a slide with a coverslip. Begin with the lowest-power objective; focus, then increase magnification and use fine focus.



Focus safely

Lowest power first. Centre the specimen; then use fine focus at higher power.

B01.21 RP Com 01 / Bio 01: recording an image

(F) (H) (T)

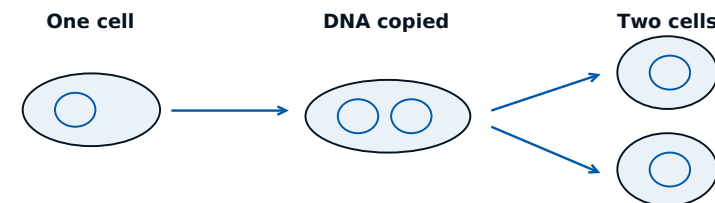
Draw clear outlines without shading; use ruled label lines and include magnification or a scale bar. A stain improves contrast. Handle slides carefully.

Culturing microorganisms

B01.T01 Binary fission

(T)

A bacterium copies its genetic material and divides into two. Under favourable conditions some bacteria divide about every 20 minutes.



Loops represent bacterial DNA, not nuclei. Each completed division doubles the population.

B01.T02 Culture media

(T)

Nutrient broth supports growth in liquid; nutrient agar supports visible colonies on a solid surface. A colony usually develops from one bacterium.

B01.T03 Bacterial population

(T)

Number of divisions = elapsed time ÷ mean division time. Final population = starting population × 2ⁿ, where n is the number of divisions.

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Culturing microorganisms	
B01.T04 (T) Growth in standard form	Starting with 100 bacteria, six divisions produce $100 \times 2^6 = 6400 = 6.4 \times 10^3$ bacteria. The model assumes constant favourable conditions.
B01.T05 (T) Aseptic technique	Sterilise media and Petri dishes; flame the inoculating loop and let it cool. Open the lid as little as possible to reduce contamination.
B01.T06 (T) Safe incubation	Secure the lid with small pieces of tape, without sealing all the way round; incubate upside down at no more than 25°C in school. This reduces contamination, condensation and growth of human pathogens.
B01.T07 (T) RP Bio 02: inhibition zones	
Compare antiseptic or antibiotic discs on an evenly inoculated agar plate. A clear zone shows inhibited growth. Use a solvent-only control disc and keep disc size, concentration, culture and incubation conditions comparable. Measure through the lid Clear-zone diameter d gives radius $r = d/2$. Area = πr^2. Compare equal discs and include a control. Illustrative results; a larger clear zone means more inhibition in this comparison.	
B01.T08 (T) RP Bio 02: measuring inhibition	Measure the clear-zone diameter through the closed dish. Radius = diameter $\div 2$; circular area = πr^2 . Repeat and compare means; a larger zone indicates greater inhibition under these conditions.
Cell division	
B01.22 (F)(H)(T) Chromosomes	Long DNA structures carrying many genes. They occur in pairs in ordinary body cells; gene and allele definitions are in B06.
B01.23 (F)(H)(T) Cell cycle	The cell grows and increases sub-cellular structures, copies its DNA, then divides.

Cell division	
B01.24 (F)(H)(T) Mitosis	Copied chromosomes separate and the nucleus divides; division of cytoplasm and membrane produces two genetically identical cells with the same chromosome number. Two body cells Same chromosome number and same genetic information. Each copied chromosome separates into two copies.
B01.25 (F)(H)(T) Uses of mitosis	Growth, repair and replacement of cells; also asexual reproduction.
B01.26 (F)(H)(T) Stem cell	An undifferentiated cell that can divide and develop into specialised cells.
B01.27 (F)(H)(T) Embryonic stem cells	Can differentiate into most types of human cell.
B01.28 (F)(H)(T) Adult stem cells	Have a more restricted range; bone-marrow stem cells can form several types of blood cell.
B01.29 (F)(H)(T) Meristems	Growing regions at plant root and shoot tips; their cells can differentiate into any plant cell type throughout life.
B01.30 (F)(H)(T) Therapeutic cloning	Produces an embryo with the patient's genes; matching stem cells reduce the risk of immune rejection.
B01.31 (F)(H)(T) Stem-cell opportunities and concerns	Potential replacement of damaged cells; risks include infection, with ethical concerns about using embryos. Plant cloning can conserve rare species or reproduce useful crops.

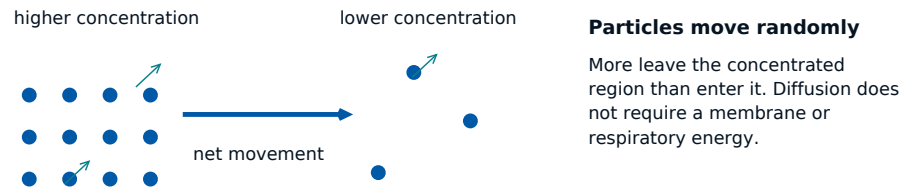
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Transport across membranes

B01.32 Diffusion (F H T)

Net movement of particles from higher to lower concentration due to random motion. No energy from respiration is required.

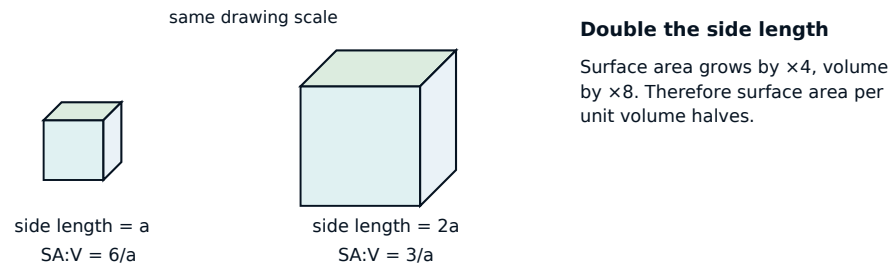


B01.33 (F H T) **Diffusion examples**
Oxygen enters cells; carbon dioxide leaves respiring cells; urea diffuses from cells into blood plasma.

B01.34 (F H T) **Faster diffusion**
A steeper concentration gradient, higher temperature and larger surface area increase the rate; a shorter diffusion path also helps.

B01.35 Surface area : volume ratio (F H T)

Surface area ÷ volume. As an organism becomes larger, this ratio decreases, making diffusion alone less sufficient.

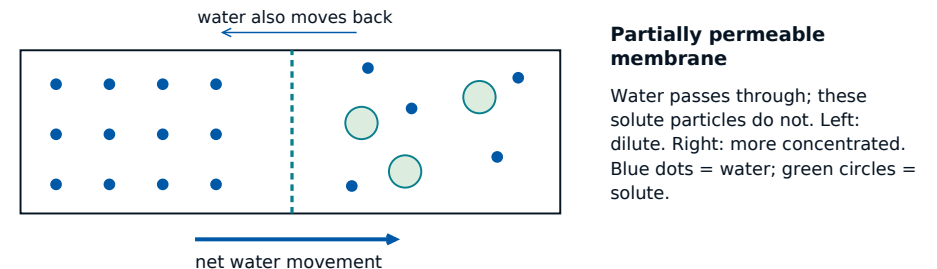


B01.36 (F H T) **Exchange surfaces**
Large area and a thin barrier shorten the route for exchange. Blood flow and ventilation maintain gradients in animal gas-exchange organs.

Transport across membranes

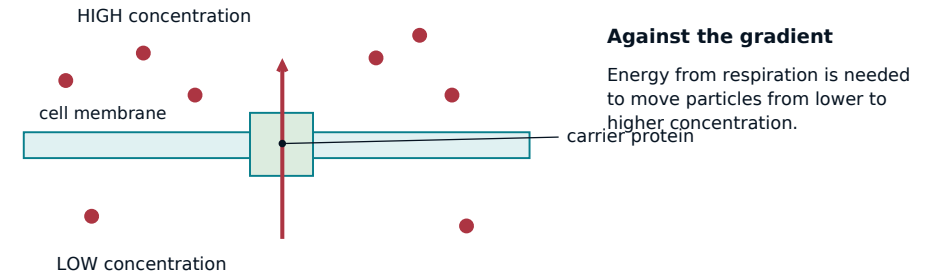
B01.37 Osmosis (F H T)

Net movement of water from a dilute solution to a more concentrated solution through a partially permeable membrane.



B01.38 Active transport (F H T)

Movement against a concentration gradient, from lower to higher concentration, requiring energy from respiration.



B01.39 (F H T) **Active transport examples**
Mineral ions enter root hair cells from dilute soil solution; glucose can enter blood from a lower concentration in the small intestine.

B01.40 (F H T) **RP Com 02 / Bio 03: plant-tissue osmosis**
Vary sugar or salt concentration; measure initial and final masses of equal-sized tissue pieces after equal immersion times. Blot consistently before weighing.

B01.41 (F H T) **RP Com 02 / Bio 03: percentage mass change**
 $100 \times (\text{final mass} - \text{initial mass}) \div \text{initial mass}$. Positive = gain; negative = loss. Control temperature, tissue source and solution volume.

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Transport across membranes

B01.42

RP Com 02 / Bio 03: no mass change

F

H

T

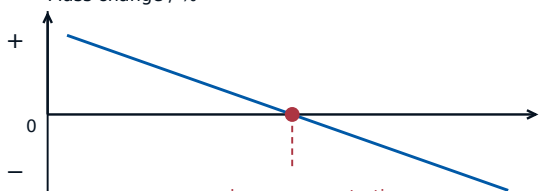
The graph's zero-change concentration estimates the concentration at which there is no net water movement. Repeat at each concentration.

Mass change / %

+

0

-



Read the intercept

Where the line crosses 0% mass change, there is no net movement of water into or out of the tissue.

18

F

 Combined Foundation

H

 Combined Higher

T

 Triple Higher

WYVERN COLLEGE / SCIENCE

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Levels of organisation

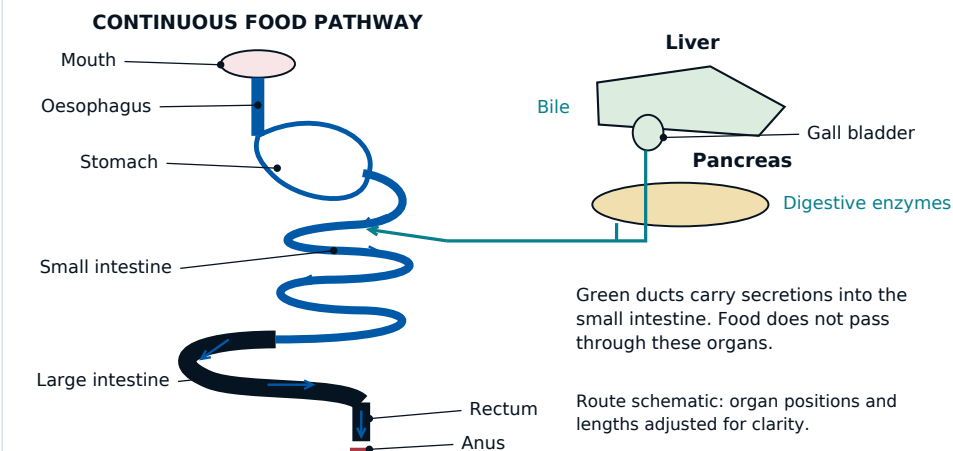
B02.01 Tissue	(F)(H)(T)	A group of cells with similar structures working together for a function.
B02.02 Organ	(F)(H)(T)	Different tissues working together for particular functions.
B02.03 Organ system	(F)(H)(T)	Organs working together; organ systems together form an organism.

Digestion and enzymes

B02.04 Digestion	(F)(H)(T)	The breakdown of large, insoluble food molecules into small, soluble molecules that can be absorbed.
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B02.05 Digestive route	(F)(H)(T)	
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Mouth → oesophagus → stomach → small intestine → large intestine → rectum → anus.

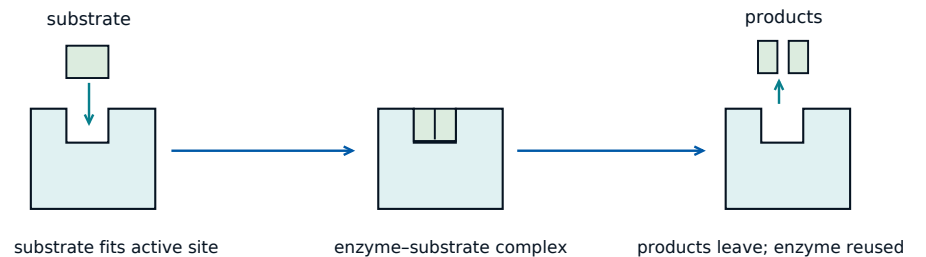


B02.06 Small intestine	(F)(H)(T)	Completes digestion and absorbs soluble products into the blood. Villi give a large surface area.
B02.07 Large intestine	(F)(H)(T)	Absorbs water from remaining material; undigested material forms faeces.

Digestion and enzymes

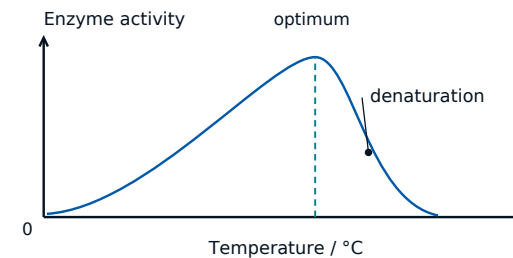
B02.08 Enzyme	(F)(H)(T)	
-------------------------	-----------	--

A biological catalyst, usually a protein, with an active site specific to its substrate.



B02.09 Temperature and enzymes	(F)(H)(T)	
--	-----------	--

Warming increases activity up to an optimum; excessive heat changes the active site's shape (denaturation).



Two different effects

Before the optimum: more frequent successful collisions. Above it: the active site changes shape. Curves depend on the enzyme.

B02.10 Enzyme pH	(F)(H)(T)	Each enzyme has an optimum pH. Large changes in pH can alter the active site and reduce activity.
B02.11 Amylase	(F)(H)(T)	Made in salivary glands, pancreas and small intestine; breaks starch into sugars.
B02.12 Protease	(F)(H)(T)	Made in stomach, pancreas and small intestine; breaks proteins into amino acids.
B02.13 Lipase	(F)(H)(T)	Made in pancreas and small intestine; breaks lipids into fatty acids and glycerol.
B02.14 Stomach acid	(F)(H)(T)	Hydrochloric acid kills many pathogens and provides acidic conditions for stomach protease.

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Digestion and enzymes

B02.15 **Bile** (F) (H) (T)
Made by the liver and stored in the gall bladder. It neutralises stomach acid and emulsifies fats into droplets, increasing lipase's working surface area.

B02.16 **Food Testing** (F) (H) (T)

RP Com 03 / Bio 04. Use separate food samples. The table groups each test, method and positive or negative result.

Sugar	Starch	Protein	Lipid	Lipid
				
brick-red Benedict's + heat	blue-black Iodine	lilac Biuret	red oil layer Sudan III	white emulsion Ethanol + water

B02.17 **Starch** (F) (H) (T)
Add iodine solution.
Positive: Orange-brown → blue-black.
Negative: Stays orange-brown.

B02.18 **Reducing sugar (e.g. glucose)** (F) (H) (T)
Add Benedict's reagent; heat in a hot-water bath.
Positive: Blue → green/yellow/orange or a brick-red precipitate.
Negative: Stays blue.

B02.18 **Protein** (F) (H) (T)
Add Biuret reagent.
Positive: Blue → lilac/purple.
Negative: Stays blue.

B02.19 **Lipids: Sudan III** (F) (H) (T)
Add Sudan III and shake gently.
Positive: A separate red-stained oil layer.
Negative: No separate red-stained oil layer.

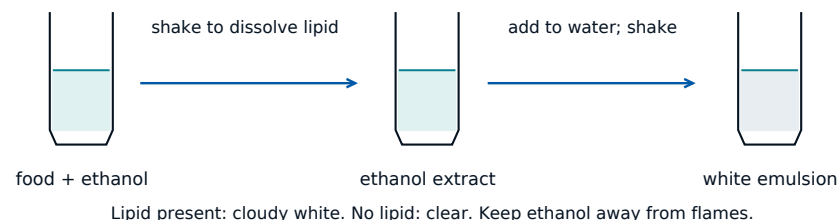
B02.R01 **Lipids: ethanol** (F) (H) (T)
Shake with ethanol; add the ethanol extract to water and shake.
Positive: Cloudy white emulsion.
Negative: Clear mixture.

Wear eye protection. Keep sample volumes consistent. Ethanol is flammable: keep it away from flames.

Digestion and enzymes

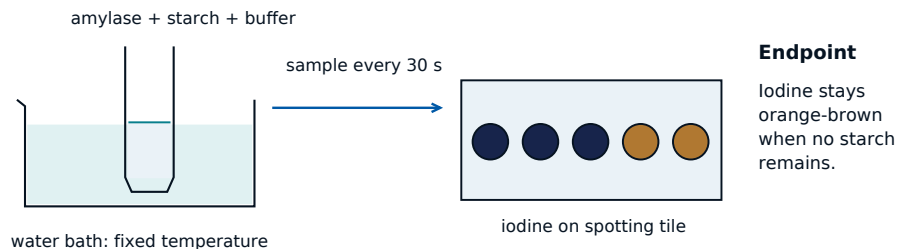
Ethanol emulsion method (F) (H) (T)

Shake the food sample with ethanol to dissolve any lipid. Add the ethanol extract to water and shake. Use a separate sample from the Sudan III test. Ethanol is flammable: keep away from flames.



B02.20 **RP Com 04 / Bio 05: amylase and pH** (F) (H) (T)

Use buffers to change pH. Mix starch and amylase; sample onto iodine every 30 s. Record when iodine stays orange-brown.



B02.21 **RP Com 04 / Bio 05: controls and rate** (F) (H) (T)
Keep temperature constant in a water bath; control enzyme/starch concentrations and volumes. For a fixed endpoint, relative rate = $1 \div \text{time}$.

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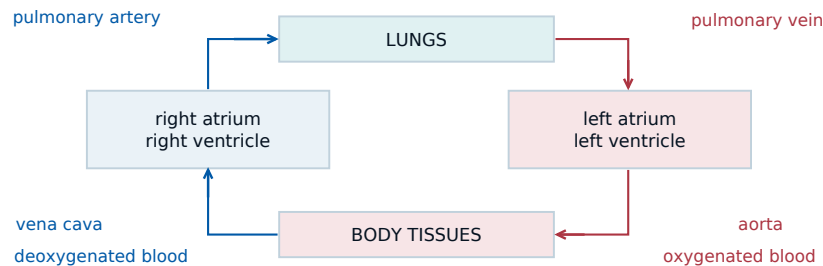
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Circulation and gas exchange

B02.22 Double circulation

(F)(H)(T)

One circuit takes blood from heart to lungs and back; the other takes blood from heart to body and back.



B02.23 Right side of heart

(F)(H)(T)

Receives deoxygenated blood through the vena cava; the right ventricle pumps it to the lungs through the pulmonary artery.

B02.24 Left side of heart

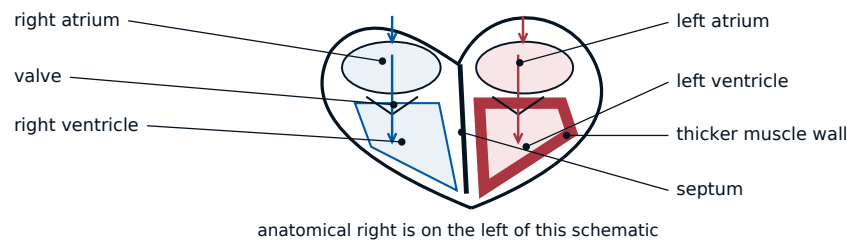
(F)(H)(T)

Receives oxygenated blood through pulmonary veins; the left ventricle pumps it to the body through the aorta.

B02.25 Ventricles and valves

(F)(H)(T)

The left ventricle has a thicker muscle wall to produce higher pressure. Valves prevent backflow.



B02.26 Coronary arteries

(F)(H)(T)

Supply the heart muscle with oxygenated blood.

B02.27 Pacemaker

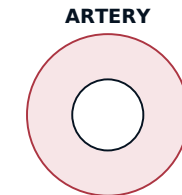
(F)(H)(T)

A group of cells in the right atrium sets the resting heart rate. An artificial pacemaker can correct irregular rhythms.

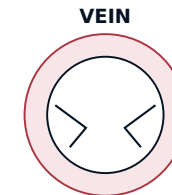
Circulation and gas exchange

Blood vessels

(F)(H)(T)



thick muscular / elastic wall



wide lumen; valves



wall one cell thick

Cross-sections are enlarged independently: capillaries are much narrower in reality.

B02.28 Artery

(F)(H)(T)

Carries blood away from the heart; thick muscular, elastic walls withstand high pressure.

B02.29 Vein

(F)(H)(T)

Carries blood towards the heart; a wide lumen and valves support low-pressure return.

B02.30 Capillary

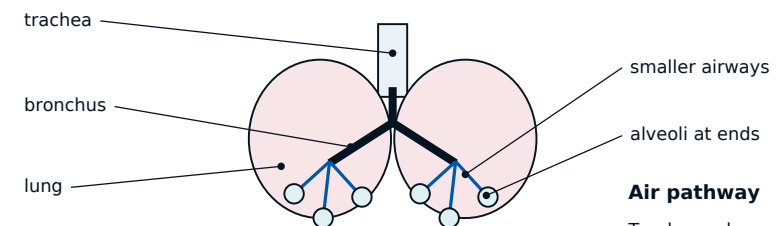
(F)(H)(T)

A narrow vessel with a wall one cell thick for rapid exchange with tissues.

B02.31 Air pathway

(F)(H)(T)

Trachea → bronchi → smaller airways → alveoli. Alveoli are surrounded by capillaries.



Air pathway

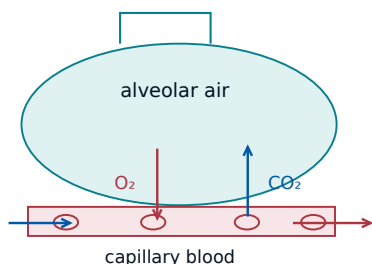
Trachea → bronchi → smaller airways → alveoli.

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Circulation and gas exchange

B02.32 Alveolar exchange (F)(H)(T)

Oxygen diffuses from alveolar air into blood; carbon dioxide diffuses from blood into alveoli. Thin, moist walls, large area and ventilation aid exchange.



Very short diffusion path

The alveolar wall and capillary wall are each one cell thick. Ventilation and blood flow maintain concentration gradients.

B02.33 (F)(H)(T)
Plasma The liquid carrying blood cells, carbon dioxide, urea, nutrients and hormones; also distributes thermal energy.

B02.34 (F)(H)(T)
Red blood cell Carries oxygen using haemoglobin; biconcave shape increases surface area, and no nucleus leaves more room for haemoglobin.

B02.35 (F)(H)(T)
White blood cell Defends against pathogens; the three defence mechanisms are in B03.

B02.36 (F)(H)(T)
Platelets Small cell fragments that help blood clot, limiting blood loss and entry of pathogens.

Health and disease

B02.37 (F)(H)(T)
Health Physical and mental wellbeing; affected by disease, diet, stress and life circumstances.

B02.38 (F)(H)(T)
Communicable / non-communicable Communicable diseases can spread between organisms; non-communicable diseases do not spread this way.

B02.39 (F)(H)(T)
Disease interactions Immune damage increases infection risk; some viruses trigger cancers; immune responses can trigger allergies; serious physical illness can affect mental health.

B02.40 (F)(H)(T)
Coronary heart disease Fatty deposits narrow coronary arteries, reducing oxygen supply to heart muscle.

B02.41 (F)(H)(T)
Stent A mesh tube that holds an artery open. It improves blood flow but requires a procedure and carries clot/infection risks.

Health and disease

B02.42 (F)(H)(T)
Statin A drug that lowers blood cholesterol, slowing fatty deposits; it requires continuing use and may cause side effects.

B02.43 (F)(H)(T)
Faulty-valve treatment Biological or mechanical replacement valves restore one-way flow; surgery and durability/clotting risks must be weighed.

B02.44 (F)(H)(T)
Heart failure treatment Transplantation can replace a failing heart but requires a donor and immune management. Artificial hearts can provide temporary support.

B02.45 (F)(H)(T)
Risk factor Something associated with a greater chance of disease. An association alone does not prove causation.

B02.46 (F)(H)(T)
Lifestyle risks Smoking raises cardiovascular, lung-disease and cancer risk; obesity raises Type 2 diabetes risk; excessive alcohol damages liver and brain. Smoking/alcohol can harm an unborn baby.

B02.47 (F)(H)(T)
Cancer Uncontrolled cell growth and division caused by cell changes; both inherited factors and environmental carcinogens can contribute.

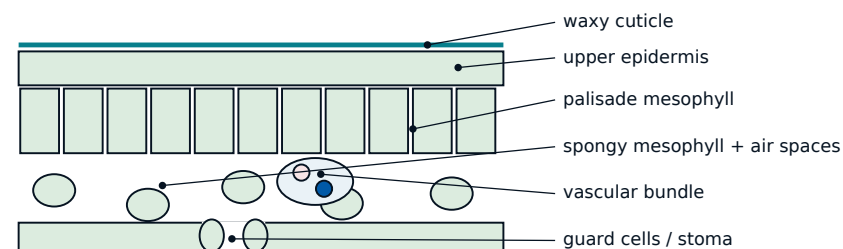
B02.48 (F)(H)(T)
Benign tumour An abnormal growth contained in one location; it does not invade other tissues.

B02.49 (F)(H)(T)
Malignant tumour Cancer cells invade nearby tissue and can spread in blood to form secondary tumours.

Plant tissues and transport

B02.50 Leaf tissues (F)(H)(T)

Epidermis protects; palisade mesophyll absorbs light; spongy mesophyll has air spaces for gas movement.



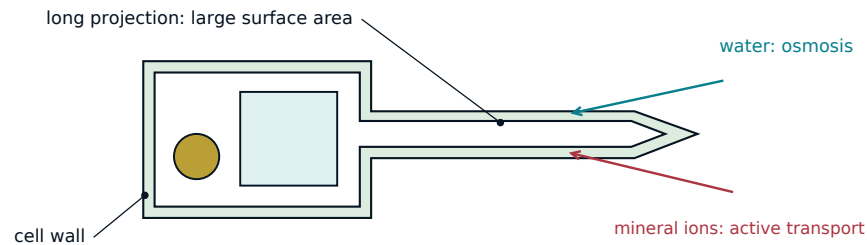
B02.51 (F)(H)(T)
Guard cells and stomata Guard cells control the opening of stomata, regulating gas exchange and water loss.

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Plant tissues and transport

B02.52 Root hair cell (F) (H) (T)

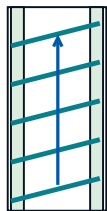
A long projection gives a large surface area for uptake of water by osmosis and mineral ions by active transport.



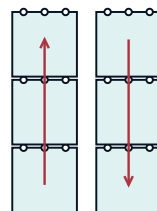
B02.53 Xylem (F) (H) (T)

Dead hollow tubes strengthened with lignin carry water and mineral ions from roots towards leaves.

XYLEM



PHLOEM



different phloem tubes shown

Water and minerals

Dead, hollow lignified tubes. Flow from roots towards leaves.

Dissolved sugars

Living tubes with porous end walls. Opposite directions can occur in different tubes, linking sources and sinks.

B02.54 (F) (H) (T) **Phloem** Living elongated cells with pores in end walls carry dissolved sugars between sources and places of use/storage.

B02.55 (F) (H) (T) **Translocation** Movement of dissolved sugars through phloem; movement can occur in either direction in different tubes.

B02.56 (F) (H) (T) **Transpiration** Water evaporates from leaf cells and diffuses out through stomata, drawing water up the xylem.

B02.57 (F) (H) (T) **Faster transpiration** Higher temperature, stronger air movement, brighter light and lower humidity generally increase water loss.

B03 | Infection and response

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MY RETRIEVAL PRACTICE

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Pathogens and transmission		
B03.01 Pathogen	(F)(H)(T)	A disease-causing microorganism or virus; GCSE groups are bacteria, viruses, fungi and protists.
B03.02 Bacterial harm	(F)(H)(T)	Bacteria reproduce rapidly and may release toxins that damage tissues.
B03.03 Viral harm	(F)(H)(T)	Viruses reproduce inside host cells and damage those cells.
B03.04 Reducing transmission	(F)(H)(T)	Hygiene, isolation, vaccination and control of vectors reduce spread by contact, droplets, contaminated water or food.
Named diseases		
B03.05 Measles	(F)(H)(T)	Virus; fever and red rash; spreads in inhaled droplets. Vaccination reduces infection and spread.
B03.06 HIV	(F)(H)(T)	Virus spread through sexual contact or infected body fluids. It damages immune cells; severe immune failure is AIDS. Antiretrovirals control viral reproduction.
B03.07 Tobacco mosaic virus	(F)(H)(T)	Causes mosaic leaf discolouration, reducing photosynthesis and growth. It can spread through contact with infected plant material.
B03.08 Salmonella	(F)(H)(T)	Bacteria in contaminated food cause fever, cramps, vomiting and diarrhoea. Hygiene, thorough cooking and poultry vaccination reduce spread.
B03.09 Gonorrhoea	(F)(H)(T)	Bacterial STI; painful urination and thick yellow/green discharge. Condoms reduce spread; appropriate antibiotics treat infection, but resistance is a problem.
B03.10 Rose black spot	(F)(H)(T)	Fungus; dark leaf spots, yellowing and early leaf loss reduce photosynthesis. Spores spread in wind/water; remove infected leaves or use fungicide.
B03.11 Malaria	(F)(H)(T)	Protist carried by mosquitoes; recurrent fever and potentially fatal disease. Nets and preventing mosquito breeding reduce transmission.
B03.12 Vector	(F)(H)(T)	An organism that transfers a pathogen between hosts; a mosquito is the vector for malaria.

Defence and medicines		
B03.13 Skin defence	(F)(H)(T)	A physical barrier; secretions inhibit pathogens and scabs seal wounds.
B03.14 Airway defence	(F)(H)(T)	Nose hairs and mucus trap particles; cilia move mucus out of trachea and bronchi towards the throat.
B03.15 Stomach defence	(F)(H)(T)	Acid kills many swallowed pathogens.
B03.16 Phagocytosis (F)(H)(T) White blood cells engulf and digest pathogens. 1 Engulf pathogen 2 Enclose it in a vesicle 3 Digest with enzymes		
B03.17 Antibodies (F)(H)(T) Proteins made by white blood cells that bind to particular pathogen antigens. antigen specific antibody binding site Shape matters Antibody binding sites are complementary to a particular antigen. The diagram shows one arm binding to the pathogen.		
B03.18 Antitoxins	(F)(H)(T)	Substances produced by white blood cells that neutralise bacterial toxins.

B03 | Infection and response

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MY RETRIEVAL PRACTICE

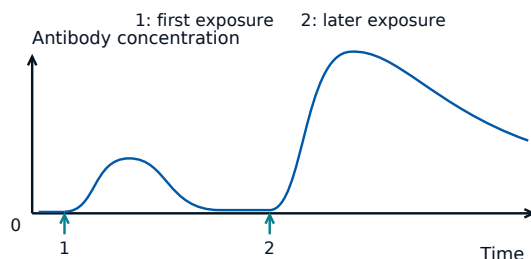
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Defence and medicines

B03.19 Vaccination

(F) (H) (T)

Exposure to harmless pathogen material stimulates a specific immune response; later exposure triggers a faster response.



Immune memory

Later exposure to the same antigen produces a faster, larger response. Vaccine material stimulates this preparation safely.

B03.20 Population vaccination

(F) (H) (T)

Fewer susceptible hosts means fewer opportunities for the pathogen to spread, helping protect vulnerable people.

B03.21 Antibiotic

(F) (H) (T)

Treats susceptible bacterial infections; antibiotics do not kill viruses. Specific bacteria require suitable antibiotics.

B03.22 Painkiller

(F) (H) (T)

Reduces symptoms such as pain; it does not kill the pathogen causing the infection.

B03.23 Antiviral challenge

(F) (H) (T)

Viruses reproduce inside body cells, making it difficult to target them without damaging host tissue.

B03.24 Antibiotic resistance

(F) (H) (T)

The evolutionary mechanism and prevention facts have their home in B06.

Drug development

B03.25 Traditional drug sources

(F) (H) (T)

Digitalis: foxgloves; aspirin: willow; penicillin: Penicillium mould, investigated by Alexander Fleming.

B03.26 Modern drug production

(F) (H) (T)

Many medicines are synthesised by chemists, often starting from naturally occurring compounds.

B03.27 Drug-test priorities

(F) (H) (T)

Toxicity = harm; efficacy = whether it works; dose = amount giving benefit with acceptable risk.

B03.28 Preclinical testing

(F) (H) (T)

Laboratory tests on cells, tissues and animals before trials in people.

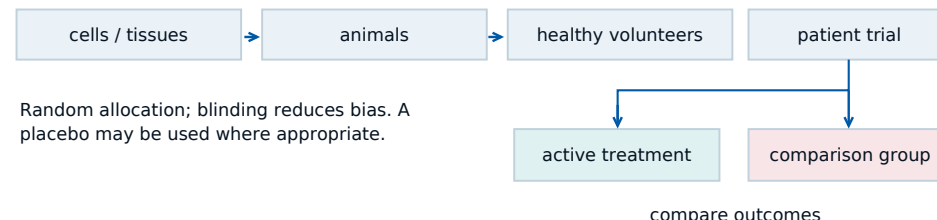
Drug development

B03.29 Clinical testing

(F) (H) (T)

Low doses are first tested for safety in volunteers; patient trials assess effectiveness and the optimum dose.

Preclinical



B03.30 Placebo

(F) (H) (T)

A treatment without the active drug, used as a comparison where appropriate.

B03.31 Double-blind trial

(F) (H) (T)

Neither participants nor the people assessing them know which treatment group they are in, reducing bias.

Monoclonal antibodies

B03.T01 Monoclonal antibody

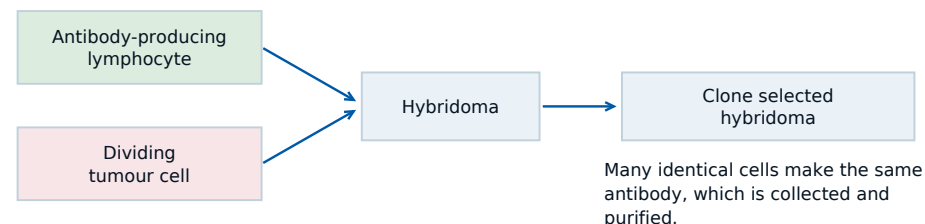
(T)

An antibody made by a clone of identical cells; all bind to the same particular site on an antigen.

B03.T02 Producing monoclonal antibodies

(T)

Stimulate a mouse lymphocyte to make the required antibody; fuse it with a tumour cell to form a hybridoma. Clone a suitable hybridoma, then collect and purify its antibodies.



The hybridoma combines antibody production with repeated division.

B03.T03 Why make a hybridoma?

(T)

The lymphocyte supplies antibody production; the tumour cell supplies the ability to keep dividing. The combined cell does both.

B03 | Infection and response

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Monoclonal antibodies

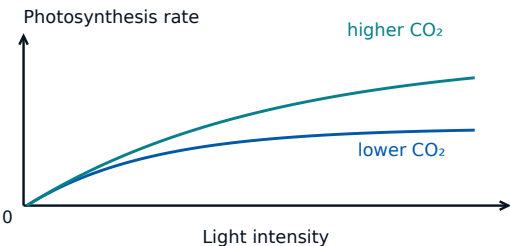
B03.T04 Diagnostic and research uses	Specific binding can detect hormones or pathogens. An attached fluorescent marker can reveal a target molecule; pregnancy tests are one diagnostic example.
B03.T05 Targeted treatment	An antibody can carry a drug or radioactive substance to cells with a matching antigen, concentrating treatment there. Specific targeting offers benefits, but side effects and ethical issues still need evaluation.

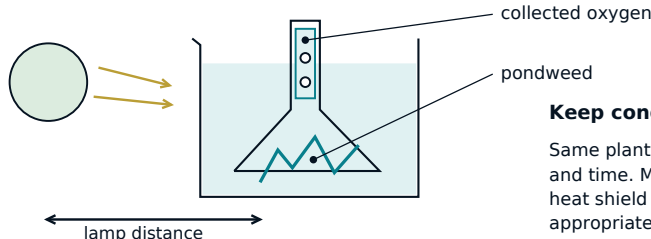
Plant disease and defence

B03.T06 Detecting plant disease	Possible signs include stunted growth, spots, rot, unusual growths, malformed leaves or stems, discolouration and visible pests. A sign alone does not identify the cause.
B03.T07 Identifying plant disease	Compare with reliable identification information, obtain laboratory analysis, or use an appropriate monoclonal-antibody test kit.
B03.T08 Plant pathogens and pests	Plants can suffer viral, bacterial or fungal disease. TMV and rose black spot are covered earlier in B03. Aphids feed on plant sap and can also transmit pathogens.
B03.T09 Mineral deficiencies	Too little nitrate limits amino-acid and protein production, causing poor growth. Too little magnesium limits chlorophyll production, causing yellow leaves (chlorosis).
B03.T10 Plant physical defences	Cellulose walls, a waxy cuticle and layers of bark form barriers to infection. Bark can shed, removing attached pathogens.
B03.T11 Plant chemical defences	Antibacterial substances inhibit microorganisms; poisons deter animals that would eat the plant.
B03.T12 Plant mechanical defences	Thorns and hairs discourage herbivores; leaves can curl or droop when touched; mimicry can make a plant less attractive to herbivores.

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Photosynthesis	
B04.01 Photosynthesis word equation	Carbon dioxide + water → glucose + oxygen; light transfers energy to chloroplasts.
B04.02 Photosynthesis formulae	$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$. Recognise CO_2 , H_2O , $\text{C}_6\text{H}_{12}\text{O}_6$ and O_2 .
B04.03 Photosynthesis energy change	Endothermic: energy is transferred from the surroundings by light and stored in products.
B04.04 Light and CO_2	Increasing either can increase photosynthesis until another factor limits the rate.
B04.05 Temperature and chlorophyll	Temperature affects enzyme activity; too high a temperature reduces it. Less chlorophyll reduces light absorption.
B04.06 Interacting limiting factors	
The factor in shortest supply relative to need limits the rate; changing another factor then has little effect.	
 Same temperature At low light, light limits both. At higher light, extra CO_2 can increase rate. A plateau shows another factor is limiting.	
B04.07 Inverse-square law	Light intensity $\propto 1 \div \text{distance}^2$ from a point source, under suitable conditions.
B04.08 Greenhouse economics	Heating, lighting and extra CO_2 can raise yield, but the extra crop value must exceed the extra cost.
B04.09 Uses of glucose	Respiration; starch storage; oil/fat storage; cellulose for cell walls; amino acids for proteins. Nitrate ions are also needed to make amino acids.

Photosynthesis	
B04.10 RP Com 05 / Bio 06: photosynthesis rate	
Change lamp distance from pondweed; measure oxygen volume per time or count bubbles over a fixed interval. Volume is better if bubble sizes vary.	
 Keep conditions constant Same plant size and species, CO_2 supply and time. Monitor temperature; use a heat shield or water bath as appropriate.	
B04.11 RP Com 05 / Bio 06: controls	Keep temperature, CO_2 supply, plant size/species and measuring time constant; allow time to adjust and repeat measurements.
Respiration and exercise	
B04.12 Cellular respiration	A continuous exothermic process in living cells that transfers energy for life processes.
B04.13 Aerobic respiration	Glucose + oxygen → carbon dioxide + water; transfers more energy per glucose molecule than anaerobic respiration.
B04.14 Aerobic formulae	$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$.
B04.15 Anaerobic respiration in muscles	Glucose → lactic acid. No oxygen is used; glucose is incompletely oxidised, so less energy is transferred.
B04.16 Anaerobic respiration in yeast	Glucose → ethanol + carbon dioxide. This fermentation is used in bread-making and alcoholic drinks.
B04.17 Uses of respiration energy	Building larger molecules, muscle contraction and maintaining body temperature.
B04.18 Exercise response	Heart rate, breathing rate and breath volume rise to increase oxygen delivery to muscles.
B04.19 Muscle fatigue	During vigorous exercise, insufficient oxygen increases anaerobic respiration and lactic acid accumulation; contractions become less efficient.

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Respiration and exercise		
B04.20	Oxygen debt	Extra oxygen needed after exercise to deal with accumulated lactic acid. Blood carries lactic acid to the liver, where it can be converted back to glucose.
Metabolism		
B04.21	Metabolism	All chemical reactions in a cell or organism, including building molecules and breaking them down.
B04.22	Carbohydrate synthesis	Glucose molecules can be joined to form starch, glycogen or cellulose.
B04.23	Lipid synthesis	One glycerol molecule combines with three fatty acid molecules to form a lipid.
B04.24	Protein synthesis and breakdown	Amino acids form proteins; breakdown of excess proteins produces urea for excretion.

B05 | Homeostasis and response

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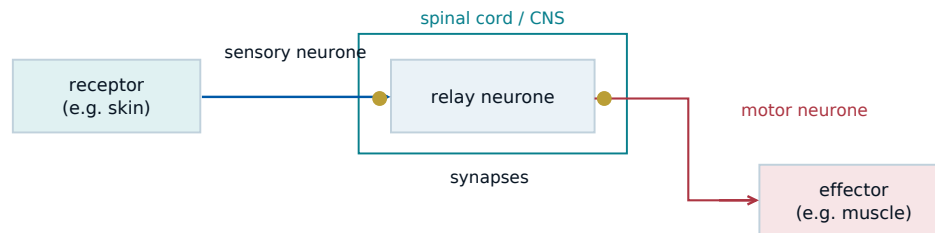
Control and nervous responses

B05.01	(F)(H)(T)	Regulation of internal conditions to keep cell and enzyme function near optimum despite changes inside or outside the body.
B05.02	(F)(H)(T)	Blood glucose concentration, body temperature and water levels.
B05.03	(F)(H)(T)	A cell or organ that detects a stimulus (a change).
B05.04	(F)(H)(T)	Receives and processes information; examples include brain, spinal cord and pancreas.
B05.05	(F)(H)(T)	A muscle that contracts or a gland that secretes to produce a response.
B05.06	(F)(H)(T)	The brain and spinal cord. Electrical impulses travel along neurones.
B05.07	(F)(H)(T)	A rapid, automatic protective response that does not require the conscious part of the brain.

Reflex arc

(F)(H)(T)

Receptor → sensory neurone → relay neurone in CNS → motor neurone → effector.

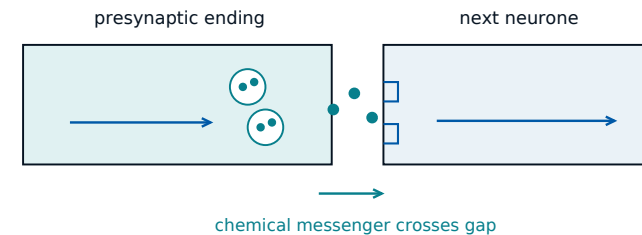


Rapid and automatic; conscious brain processing is not needed before the response.

Control and nervous responses

B05.09 Synapse (F)(H)(T)

A gap between neurones; a chemical messenger diffuses across and triggers an impulse in the next neurone.

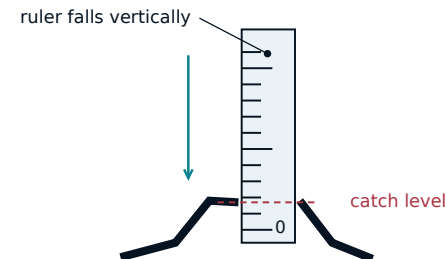


Signal changes form

Electrical impulse → chemical diffusion → new electrical impulse.

B05.10 RP Com 06 / Bio 07: reaction time (F)(H)(T)

Drop a ruler without warning and record the distance fallen before it is caught. Convert using a supplied table; repeat and calculate a mean.



Start from zero

Before release, align 0 cm with the top of the thumb. Drop without warning. Read the catch distance, then use the conversion table.

B05.11 (F)(H)(T) RP Com 06 / Bio 07: fair comparison

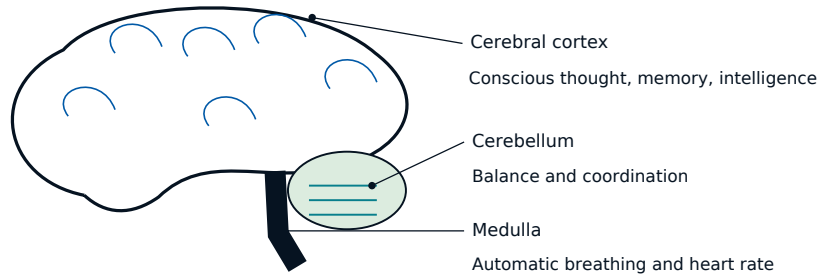
Change one safe factor; control starting position, hand and method. Allow practice and avoid anticipation. Typical reaction times are about 0.2-0.9 s.

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Brain and eye

B05.T01 Brain regions T

Cerebral cortex: conscious thought, memory and intelligence. Cerebellum: balance and coordination. Medulla: automatic activities such as breathing and heart rate.

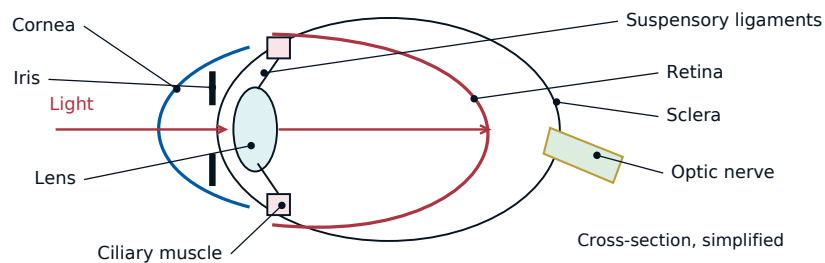


B05.T02 Investigating the brain T

Damage studies, electrical stimulation and MRI help link regions to functions. Many interconnected neurones and delicate tissue make interpretation and treatment difficult; procedures can damage essential functions.

B05.T03 Eye structures T

Cornea refracts incoming light; iris controls pupil size; lens fine-tunes focus. Retina contains light-sensitive receptors; optic nerve carries impulses to the brain; sclera is a tough protective coat.



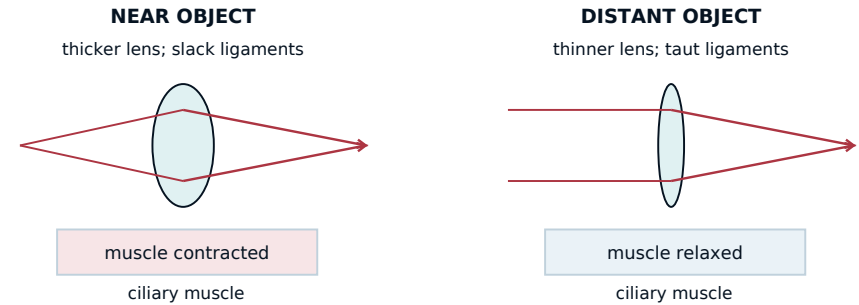
B05.T04 Controlling the lens T

Ciliary muscles and suspensory ligaments alter lens shape. Accommodation brings the image into focus on the retina.

Brain and eye

B05.T05 Near focus T

Ciliary muscles contract; suspensory ligaments slacken; the lens becomes thicker and refracts light more strongly.



B05.T06 Distant focus T

Ciliary muscles relax; ligaments become taut; the lens is pulled thinner and refracts light less strongly.

B05.T07 Pupil response T

In bright light, circular iris muscles contract and radial muscles relax, reducing pupil size. In dim light the opposite occurs, admitting more light.



B05 | Homeostasis and response

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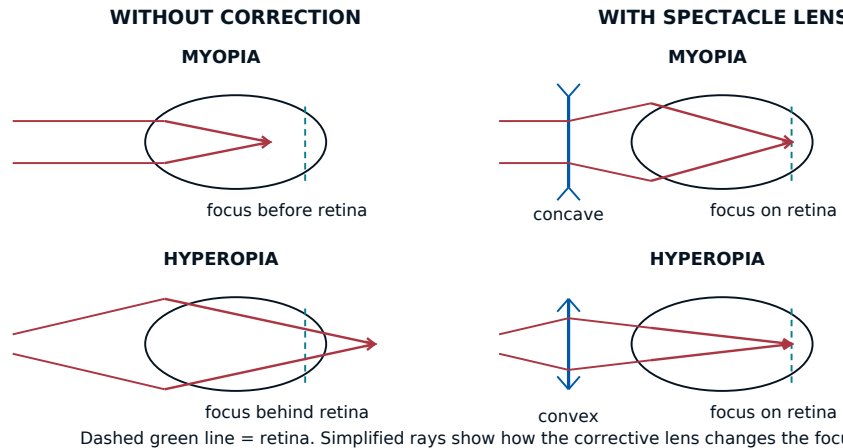
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Brain and eye

B05.T08 **Myopia** (T)

Short sight: distant light focuses in front of the retina. A concave (diverging) spectacle lens spreads rays before they enter the eye.



B05.T09 (T)
Hyperopia Long sight: light from near objects would focus behind the retina. A convex (converging) lens brings the focus forwards onto the retina.

B05.T10 (T)
Correcting sight Glasses or contact lenses change refraction. Laser surgery reshapes the cornea; a replacement lens changes focusing power. Compare suitability, benefits and procedural risks using evidence.

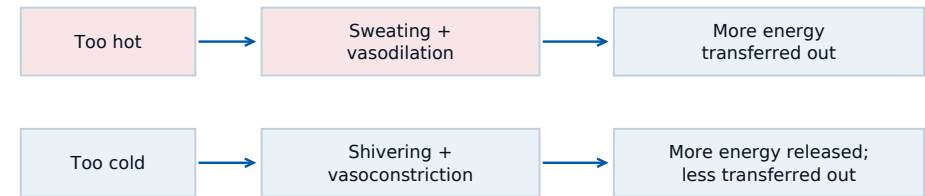
Temperature regulation

B05.T11 (T)
Thermoregulatory centre The brain monitors blood temperature; skin receptors also send temperature information to this centre.

Temperature regulation

B05.T12 **Cooling the body** (T)

Sweat evaporation transfers energy from the skin. Vasodilation increases blood flow near the skin, increasing energy transfer to the surroundings.



Responses reduce the temperature change: negative feedback.

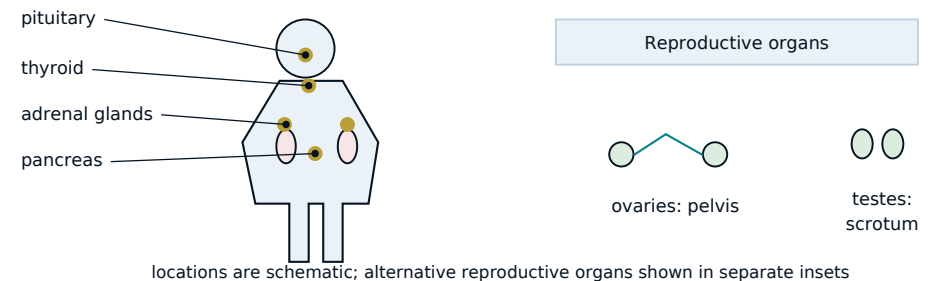
B05.T13 (T)
Warming the body Vasoconstriction reduces blood flow near the skin and reduces energy loss. Sweating stops; shivering muscle contractions increase respiration and energy transfer.

Endocrine system and glucose

B05.12 (F) (H) (T)
Hormone A chemical messenger secreted by an endocrine gland into blood; it acts on target organs. Effects are usually slower and longer-lasting than nervous responses.

B05.13 **Endocrine gland locations** (F) (H) (T)

Pituitary: brain; thyroid: neck; adrenals: above kidneys; pancreas: abdomen; ovaries: pelvis; testes: scrotum.



The pituitary releases hormones in response to body conditions; some stimulate other endocrine glands.

High blood glucose triggers insulin release. It promotes glucose uptake and storage as glycogen in liver and muscle.

Glands and hormones: comparison table on page 32.

B05 | Homeostasis and response

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Endocrine glands and hormones

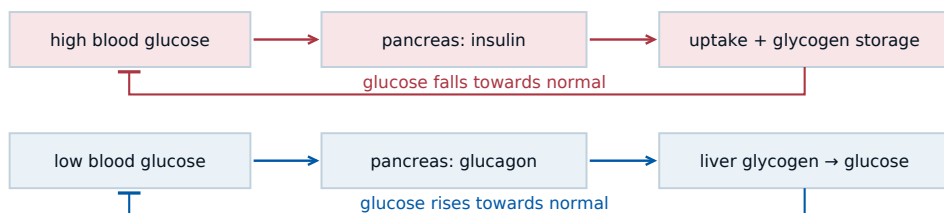
GLAND	HORMONES RELEASED	
B05.14 Pituitary gland	FSH and LH ADH	(F) (H) (T) (T)
B05.15 Pancreas	Insulin Glucagon	(F) (H) (T) (H) (T)
B05.R01 Adrenal glands	Adrenaline	(H) (T)
B05.R02 Thyroid gland	Thyroxine	(H) (T)
B05.R03 Ovaries	Oestrogen and progesterone	(F) (H) (T)
B05.R04 Testes	Testosterone	(F) (H) (T)

Endocrine system and glucose

B05.16 Type 1 diabetes	(F) (H) (T)	The pancreas produces insufficient insulin; insulin treatment controls blood glucose.
B05.17 Type 2 diabetes	(F) (H) (T)	Cells respond less effectively to insulin. Diet management and exercise help control it; obesity increases risk.
B05.18 Glucagon	(H) (T)	Released by the pancreas when blood glucose is low; promotes conversion of liver glycogen to glucose and release into blood.
B05.19 Glucose negative feedback	(H) (T)	

Insulin lowers high glucose; glucagon raises low glucose. As the level returns towards normal, the corrective signal decreases.

Negative feedback: the corrective response reduces the original stimulus.

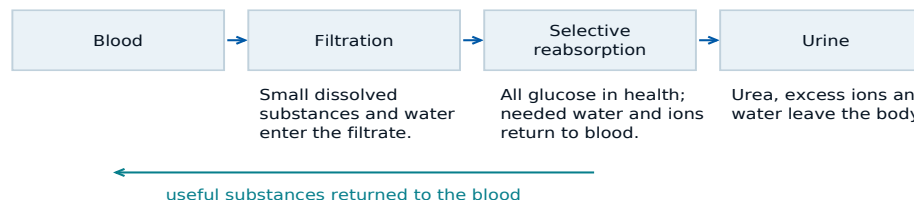


Water and nitrogen balance

B05.T14 Water and solute loss	(T)	Water is lost through breathing; sweat removes water, ions and some urea. These losses are not directly adjusted to control blood composition. Kidneys regulate excretion in urine.
B05.T15 Why control water balance?	(T)	Very dilute body fluids can make cells gain water by osmosis; very concentrated fluids make cells lose water. Either change can disrupt cell function.
B05.T16 Urea formation	(T)	Excess amino acids are deaminated in the liver, producing toxic ammonia, which is rapidly converted into urea. Blood carries urea to the kidneys for excretion.

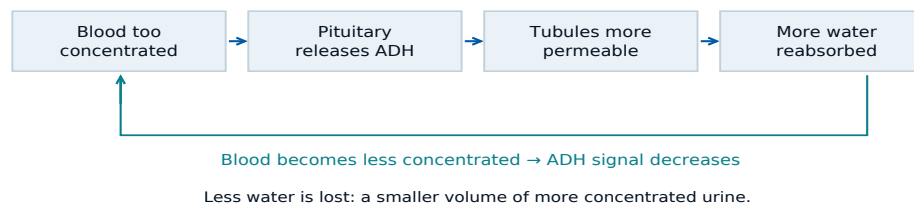
B05.T17 Kidney function (T)

Blood is filtered; useful glucose, the required water and some ions are selectively reabsorbed. Urea with excess water and ions leaves as urine.



B05.T18 ADH feedback (T)

Concentrated blood triggers more ADH release from the pituitary. Kidney tubules become more permeable to water, so more water returns to blood and less, more concentrated urine forms.



B05.T19 Too much water	(T)	Dilute blood reduces ADH release; kidney tubules reabsorb less water. A larger volume of dilute urine helps restore blood concentration.
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B05 | Homeostasis and response

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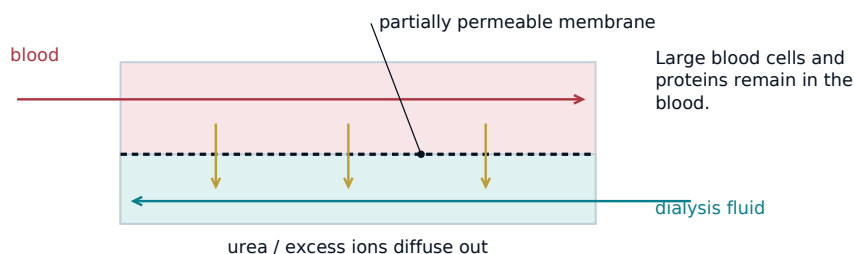
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Water and nitrogen balance

B05.T20 Dialysis

(T)

Blood flows beside dialysis fluid across a partially permeable membrane. Urea and excess ions diffuse out; suitable glucose and ion concentrations in the fluid avoid loss of needed substances.



B05.T21 Kidney failure treatments

(T)

Dialysis needs repeated sessions and diet/fluid control. A successful transplant can restore continuous kidney function but needs a suitable donor, surgery and anti-rejection drugs.

Reproductive hormones

B05.20 Puberty

(F) (H) (T)

Reproductive hormones cause secondary sexual characteristics to develop.

B05.21 Testosterone

(F) (H) (T)

Made in testes; stimulates sperm production.

B05.22 Oestrogen

(F) (H) (T)

Made in ovaries; develops female secondary sexual characteristics and helps rebuild the uterus lining.

B05.23 Ovulation

(F) (H) (T)

Release of a mature egg from an ovary, roughly once per 28-day cycle, with individual variation.

B05.24 FSH

(F) (H) (T)

From the pituitary; stimulates maturation of an egg in the ovary.

B05.25 LH

(F) (H) (T)

From the pituitary; triggers ovulation.

B05.26 Progesterone

(F) (H) (T)

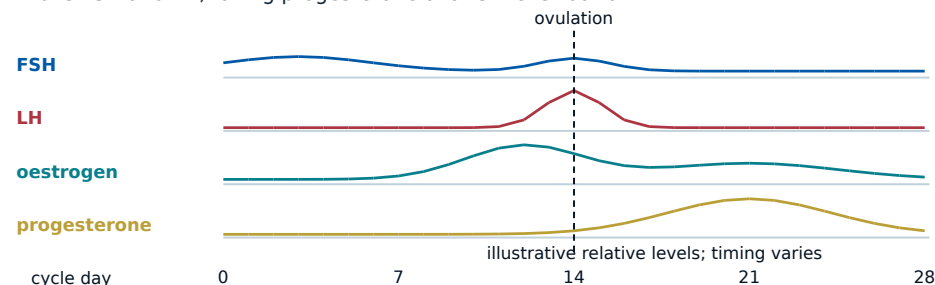
Helps maintain the uterus lining after ovulation.

Reproductive hormones

B05.27 Hormone interactions

(H) (T)

FSH stimulates oestrogen; oestrogen inhibits FSH and stimulates an LH surge. Progesterone inhibits FSH and LH; falling progesterone allows menstruation.



Fertility control and feedback

B05.28 Hormonal contraception

(F) (H) (T)

Oral contraceptives inhibit FSH; progesterone implants, injections or patches suppress egg maturation/release.

B05.29 Barrier contraception

(F) (H) (T)

Condoms and diaphragms prevent sperm reaching an egg; condoms also reduce STI transmission.

B05.30 Other contraception

(F) (H) (T)

IUDs, spermicides, avoiding intercourse around ovulation and surgical sterilisation act in different ways. Compare effectiveness, side effects, permanence and STI protection.

B05.31 Fertility drugs

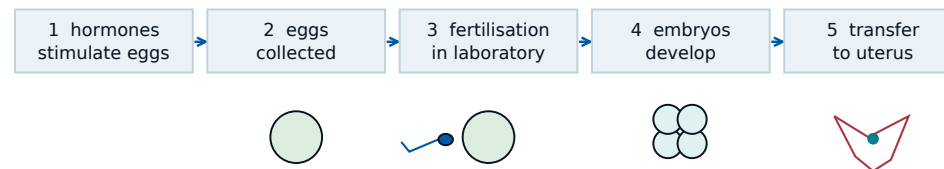
(H) (T)

FSH and LH can stimulate egg maturation and ovulation.

B05.32 IVF sequence

(H) (T)

Hormones stimulate several eggs → eggs collected → fertilised in a laboratory → embryos develop → embryo(s) placed in uterus.



Fertilisation happens outside the body; an embryo is then placed in the uterus.

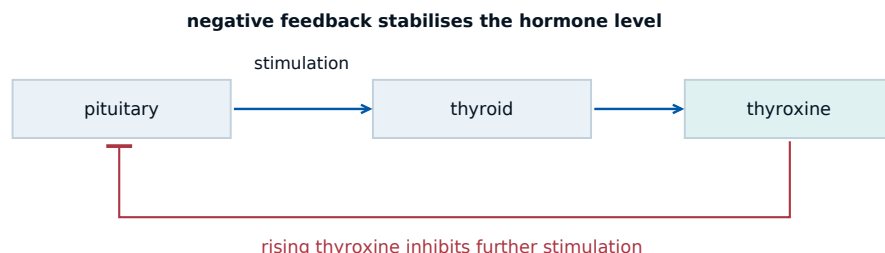
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Fertility control and feedback

B05.33 IVF limitations	(H) (T)	Physically/emotionally demanding; not always successful; transferring multiple embryos increases multiple-birth risks.
B05.34 Adrenaline	(H) (T)	From adrenal glands during fear/stress; increases heart rate and delivery of oxygen and glucose for fight or flight.
B05.35 Thyroxine	(H) (T)	From the thyroid; controls basal metabolic rate and supports growth and development.

B05.36 Thyroxine feedback (H) (T)

Low thyroxine stimulates pituitary signals to the thyroid; rising thyroxine inhibits further stimulation.

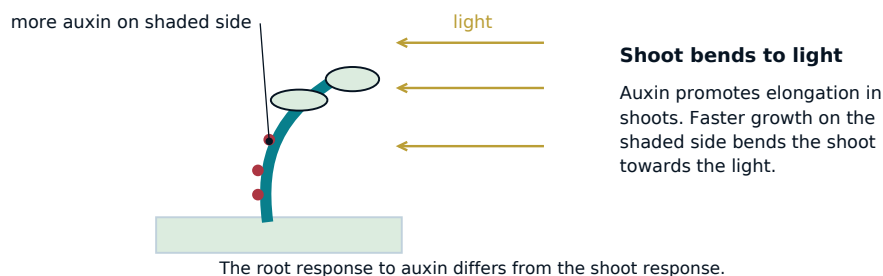


Plant responses

B05.T22 Tropism	(T)	Directional growth in response to a stimulus. Shoots normally grow towards light and against gravity; roots normally grow with gravity.
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B05.T23 Auxin and shoots (T)

Unequal auxin distribution causes unequal cell elongation. More auxin on a shoot's shaded side makes that side grow faster, bending the shoot towards light.

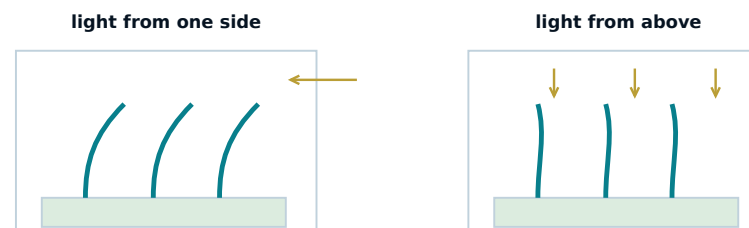


Plant responses

B05.T24 Auxin and gravity	(T)	In a horizontal shoot, more auxin on the lower side promotes elongation, bending it upwards. In roots, higher auxin inhibits elongation on the lower side, bending the root downwards.
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B05.T25 RP Bio 08: seedling responses (T)

Compare light from one side with suitable controls, or compare seedling orientations to investigate gravity. Keep species, age, water and temperature comparable; measure growth and make labelled drawings.



Same seedling species, starting age, water and temperature; measure growth and draw responses.

B05.T26 Gibberellins and ethene	(T)	Gibberellins stimulate germination. Ethene regulates cell division and fruit ripening.
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B05.T27 Using plant hormones	(T)	Auxins: selective weedkillers, rooting powders and tissue culture. Gibberellins: end dormancy, encourage flowering and enlarge fruit. Ethene: control ripening during transport and storage.
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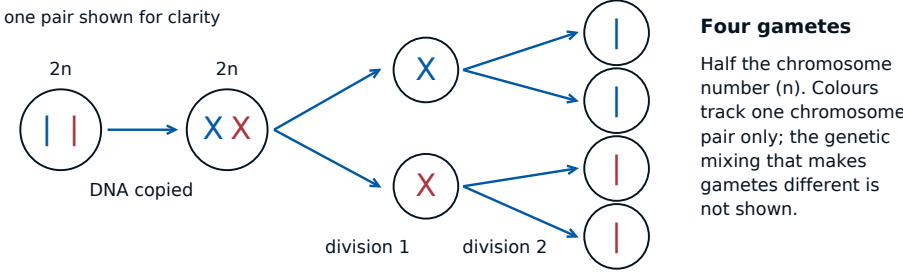
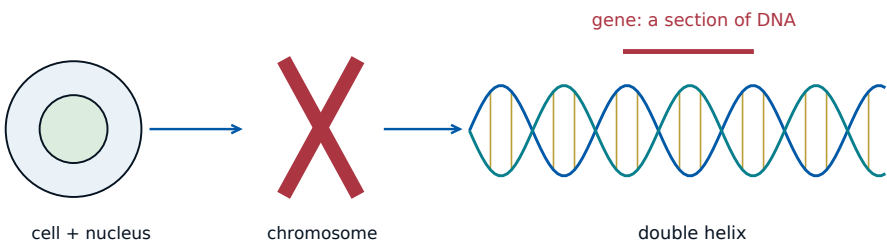
B06 | Inheritance, variation and evolution

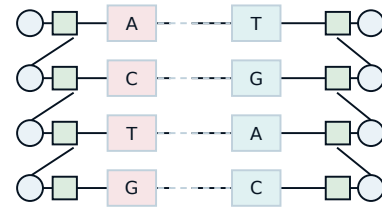
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Reproduction and DNA		
B06.01	Sexual reproduction	Male and female gametes fuse, mixing genetic information and producing variation.
B06.02	Asexual reproduction	One parent, no gamete fusion; mitosis produces genetically identical offspring (clones), except for mutations.
B06.03	Meiosis	
DNA is copied once and the cell divides twice, producing four genetically different gametes with half the original chromosome number. 		
B06.04	Fertilisation	Fusion of gametes restores the full chromosome number; the new cell then divides by mitosis.
B06.05	DNA	
A polymer of two strands wound into a double helix. 		
B06.06	Gene	A section of DNA coding for a particular amino acid sequence to make a protein.
B06.07	Genome	All the genetic material of an organism.

Reproduction and DNA		
B06.08	Human-genome research	Helps identify disease-linked genes, understand inherited disorders and trace past human migration.
Reproductive strategies		
B06.T01	Sexual reproduction: trade-offs	Genetic variation can help a population survive environmental change. Finding a mate and producing gametes takes time and energy; reproduction may be slower.
B06.T02	Asexual reproduction: trade-offs	One parent can produce many offspring rapidly without finding a mate. Identical offspring suit stable conditions, but low variation can leave a population vulnerable to the same change.
B06.T03	Using both methods	Malaria parasites reproduce asexually in people and sexually in mosquitoes. Many fungi use both methods. Strawberries form runners and seeds; daffodils divide bulbs as well as producing seeds.
DNA and protein synthesis		
B06.T04	DNA nucleotide	
Each nucleotide contains a sugar, a phosphate and one of four bases: A, T, C or G. Alternating sugars and phosphates form each strand's backbone.  One nucleotide: phosphate + sugar + base		
B06.T05	Triplet code	The sequence of three DNA bases specifies an amino acid. The order of triplets determines the amino-acid sequence of a protein.
B06.T06	Complementary base pairs	A pairs with T; C pairs with G on the other DNA strand. This pairing makes the strands complementary.

B06 | Inheritance, variation and evolution

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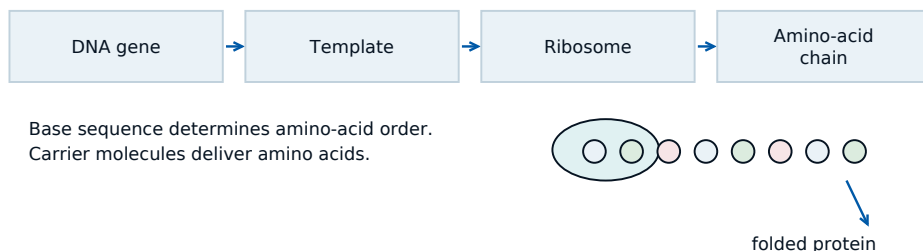
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DNA and protein synthesis

B06.T07 Making a protein (T)

A template carrying the gene's information directs assembly at a ribosome. Carrier molecules deliver the correct amino acids, which join into a chain and then fold into a functional protein.



B06.T08 (T)
Coding mutations A changed base sequence may alter the amino-acid sequence and folding, changing an enzyme's active site or a structural protein. Many mutations have little or no effect.

B06.T09 (T)
Non-coding variants Some DNA regulates when genes are switched on or off. A change there may alter the amount or timing of protein production and therefore the phenotype.

Inheritance vocabulary

B06.09 (F) (H) (T)	Allele	An alternative version of a gene.
B06.10 (F) (H) (T)	Genotype	The alleles an organism has.
B06.11 (F) (H) (T)	Phenotype	The observable characteristics produced by genotype interacting with the environment.
B06.12 (F) (H) (T)	Dominant allele	Expressed when at least one copy is present.
B06.13 (F) (H) (T)	Recessive allele	For the simple two-allele examples studied, expressed only when no dominant allele is present.
B06.14 (F) (H) (T)	Homozygous	Two identical alleles for a gene.
B06.15 (F) (H) (T)	Heterozygous	Two different alleles for a gene.

Inheritance vocabulary

B06.16 Punnett square (F) (H) (T)

Rows and columns show parental gametes; cells show possible offspring allele combinations. Each fertilisation is an independent event.

parent gametes

	A	a
A	AA	Aa
a	Aa	aa

Aa x Aa

Each cell combines one allele from each parent. Expected genotypes: 1 AA : 2 Aa : 1 aa. With complete dominance, expected phenotypes are 3 : 1.

B06.17 (H) (T)
Constructing a genetic cross Choose allele symbols, identify parent genotypes, write gametes and combine one allele from each parent in every cell.

B06.18 (F) (H) (T)
Polygenic characteristic A characteristic influenced by several genes, rather than a single gene.

B06.19 (F) (H) (T)
Polydactyly Extra fingers or toes; in the GCSE model, caused by a dominant allele.

B06.20 (F) (H) (T)
Cystic fibrosis An inherited disorder of cell membranes caused by a recessive allele; a heterozygote is an unaffected carrier.

B06.21 (F) (H) (T)
Embryo screening Can identify particular inherited disorders; consider accuracy, cost, embryo selection and ethical concerns.

B06.22 (F) (H) (T)
Human chromosomes and sex Body cells normally have 23 pairs. In the GCSE model, XX is female and XY male; eggs carry X, sperm carry X or Y.

B06 | Inheritance, variation and evolution

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MY RETRIEVAL PRACTICE

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Inheritance vocabulary

B06.23 **Sex inheritance** (F) (H) (T)

An XX × XY cross gives an expected 1:1 ratio of XX to XY offspring; this does not guarantee equal numbers in a family.

	X (egg)	X (egg)
X (sperm)	XX	XX
Y (sperm)	XY	XY

Expected ratio 1:1

Each fertilisation is independent. This model predicts probabilities, not a guaranteed family composition.

Variation and selection

B06.24 (F) (H) (T) **Variation** Differences between individuals caused by genes, environment or both.

B06.25 (F) (H) (T) **Mutation** A change in DNA that can create a new allele. Most have no phenotypic effect, some influence phenotype, and very few determine it.

B06.26 (F) (H) (T) **Evolution** Change in inherited characteristics of a population over generations.

B06.27 **Natural selection** (F) (H) (T)

Inherited variation → competition → better-adapted individuals reproduce more → advantageous alleles become more common.



The population changes over generations; an individual does not evolve a trait because it needs it.

B06.28 (F) (H) (T) **Species formation** Populations can become so different that they can no longer interbreed to produce fertile offspring.

Variation and selection

B06.29 (F) (H) (T) **Selective breeding** Humans choose parents with useful traits, then select and breed suitable offspring over many generations.

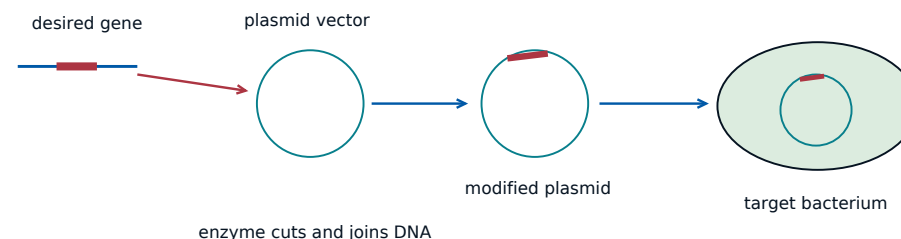
B06.30 (F) (H) (T) **Selective-breeding examples** Disease-resistant crops, high-yield livestock, gentle dogs or large flowers. Inbreeding can increase inherited-defect risk.

B06.31 (F) (H) (T) **Genetic engineering** Introducing a gene into an organism's genome to give a desired characteristic.

B06.32 (F) (H) (T) **Genetic-engineering uses** Bacteria can produce human insulin; crops can resist pests/herbicides or have higher yields. Consider ecological effects and evidence about benefits/risks.

B06.33 **Gene transfer** (H) (T)

Enzymes isolate a gene and insert it into a vector, such as a plasmid or virus; the vector transfers it into target cells early in development.



Cloning

B06.T10 (T) **Plant cloning** Cuttings grow into plants genetically identical to the parent. Tissue culture grows small groups of plant cells in suitable conditions to produce many clones, useful for rare plants or commercial crops.

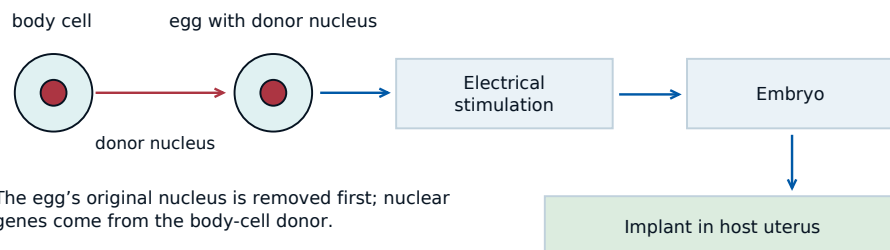
B06.T11 (T) **Embryo cloning** Split cells from an early embryo before specialisation and implant the resulting embryos into host mothers. The offspring have the same genetic information as each other.

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Cloning

B06.T12 Adult-cell cloning T

Replace an unfertilised egg's nucleus with an adult body-cell nucleus. Stimulate division electrically; implant the resulting embryo into a host mother. Nuclear genes match the body-cell donor.



B06.T13 Cloning: evaluation T
Can reproduce desirable characteristics or help conservation. Low genetic variation can increase shared vulnerability; low success rates and animal welfare raise concerns.

Development of evolutionary ideas

B06.T14 Darwin's evidence T
Voyage observations, experiments and fossil and geological evidence helped Darwin develop natural selection. He published *On the Origin of Species* in 1859.

B06.T15 Why acceptance took time T
The theory challenged existing beliefs; evidence was initially incomplete and the mechanism of inheritance was not yet understood. Later evidence strengthened the explanation.

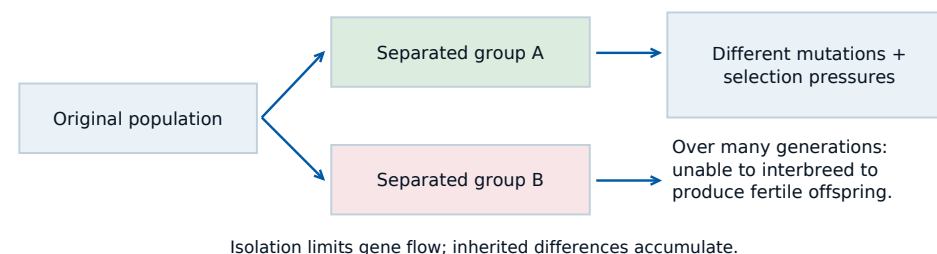
B06.T16 Lamarck's proposal T
Suggested acquired changes could be inherited. Ordinary acquired changes, such as larger muscles through use, are generally not passed on genetically.

B06.T17 Wallace's contribution T
Independently developed natural selection; joint work appeared with Darwin in 1858. Studies of species distributions and warning colours helped develop evolutionary explanations.

Development of evolutionary ideas

B06.T18 Speciation T

Separated populations experience different mutations and selection pressures. Over many generations their inherited differences may become large enough that they cannot interbreed to produce fertile offspring.



B06.T19 Mendel's experiments T
Breeding pea plants led Mendel to infer inherited units passed from parents to offspring. These units are now called genes.

B06.T20 Development of genetics T
Mendel's work was initially little known and the cellular mechanism was unclear. Later chromosome observations linked genes to chromosomes; DNA structure and function explained inheritance molecularly.

Evidence, extinction and classification

B06.34 Evolution evidence F H T
Fossils, inherited genes and the development of antibiotic-resistant bacteria support evolution by natural selection.

B06.35 Fossil formation F H T
Preserved remains where decay is prevented; mineral replacement; or traces such as footprints and burrows.

B06.36 Incomplete fossil record F H T
Soft bodies often leave no fossils; geological processes destroy evidence, especially from early life.

B06.37 Extinction F H T
No living individuals of a species remain; causes include environmental change, new predators/pathogens, competition or catastrophic events.

B06 | Inheritance, variation and evolution

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MY RETRIEVAL PRACTICE

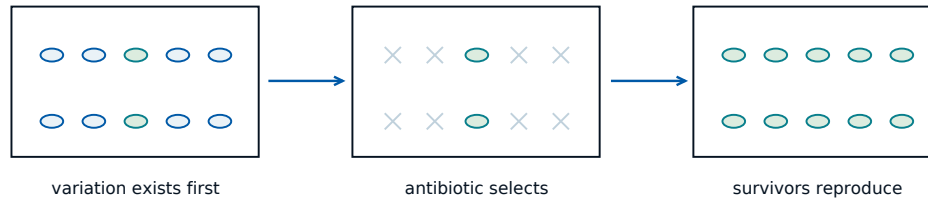
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Evidence, extinction and classification

B06.38 **Antibiotic resistance mechanism** (F) (H) (T)

Random mutations create resistant bacteria; antibiotics kill susceptible bacteria, leaving resistant ones to reproduce and spread.

Green = resistant variant; antibiotics do not create the useful mutation on demand.



B06.39 (F) (H) (T)
Slowing resistance Avoid inappropriate antibiotic use; follow the prescribed course and restrict unnecessary agricultural use. New antibiotics take time and money to develop.

B06.40 (F) (H) (T)
Linnaean groups Kingdom → phylum → class → order → family → genus → species.

B06.41 (F) (H) (T)
Binomial name Two-part scientific name: genus followed by species, for example *Homo sapiens*.

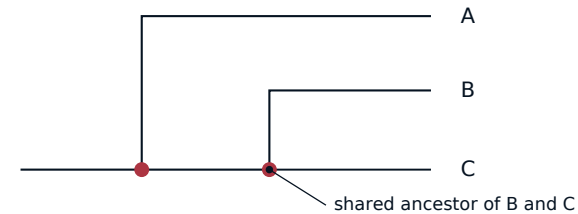
B06.42 (F) (H) (T)
Three domains Carl Woese's system: Archaea, Bacteria and Eukaryota, based on molecular evidence. Eukaryota includes animals, plants, fungi and protists.

B06.43 (F) (H) (T)
Changing classification Better microscopy and biochemical/genetic evidence can reveal relationships that external appearance alone misses.

Evidence, extinction and classification

B06.44 **Evolutionary tree** (F) (H) (T)

Branch points represent common ancestors; more recent shared ancestors indicate closer relationships.



Read branch points

B and C share a more recent common ancestor with each other than with A. The left-to-right axis represents evolutionary history.

Evolution evidence links

B06.T21 (T)
Evolution evidence links Use the fossil, extinction and antibiotic-resistance items in this B06 unit alongside natural selection. The shared evidence links to AQA Separate Biology sections 4.6.3.4-4.6.3.7.

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Communities and adaptations		
B07.01	(F)(H)(T)	All organisms of one species in a habitat.
Population		
B07.02	(F)(H)(T)	All the populations of different species living in a habitat.
Community		
B07.03	(F)(H)(T)	A community interacting with the non-living conditions of its environment.
Ecosystem		
B07.04	(F)(H)(T)	Species depend on each other for resources or services such as food, shelter, pollination and seed dispersal.
Interdependence		
B07.05	(F)(H)(T)	Populations and environmental conditions remain broadly balanced over time.
Stable community		
B07.06	(F)(H)(T)	Usually for light, space, water and mineral ions.
Plant competition		
B07.07	(F)(H)(T)	Usually for food, mates and territory.
Animal competition		
B07.08	(F)(H)(T)	A non-living influence: light, temperature, water, soil pH/minerals, wind, CO ₂ or dissolved oxygen.
Abiotic factor		
B07.09	(F)(H)(T)	A living influence: food availability, predators, pathogens or competitors.
Biotic factor		
B07.10	(F)(H)(T)	Structural: body feature; behavioural: action; functional: internal process. Each can improve survival in a particular environment.
Adaptation types		
B07.11	(F)(H)(T)	An organism adapted to extreme conditions, such as high temperature, pressure or salt concentration.
Extremophile		
Feeding and sampling		
B07.12	(F)(H)(T)	An organism, usually a plant or alga, that makes organic molecules by photosynthesis.
Producer		
B07.13	(F)(H)(T)	Primary consumers eat producers; secondary consumers eat primary consumers; tertiary consumers eat secondary consumers.
Consumer levels		

Feeding and sampling		
B07.14	Food-chain arrow	(F)(H)(T)
Points from the organism eaten to the eater, showing the direction of biomass/energy transfer.		
<pre> graph LR grass[grass] --> rabbit[rabbit] rabbit --> fox[fox] </pre> producer primary consumer secondary consumer The arrow points from food to feeder: the direction of biomass / energy transfer.		
B07.15	Predator-prey cycles	(F)(H)(T)
Prey numbers often rise first, followed by predators; more predators reduce prey, then predator numbers fall.		
Population size prey predator 0 Time Predator peaks lag Food supply rises first; predator numbers respond later. These are illustrative patterns, not measured data.		
B07.16	RP Com 07 / Bio 09: random quadrats	(F)(H)(T)
Choose random coordinates, count the species in each quadrat and sample enough locations to reduce bias.		
y x coordinate → Avoid selection bias Generate random x and y coordinates. Place a quadrat at each selected point, then use the same counting rule throughout.		

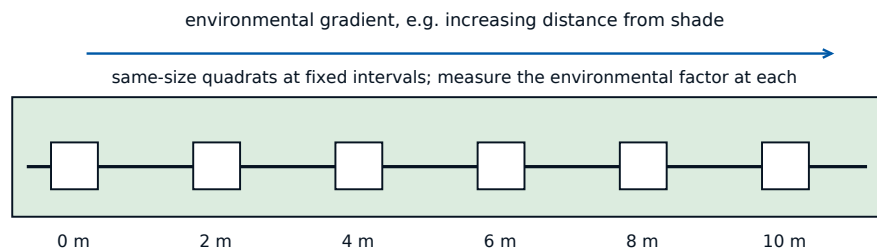
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Feeding and sampling

B07.17 **RP Com 07 / Bio 09: population estimate** (F) (H) (T)
 Mean number per quadrat × total habitat area ÷ quadrat area. Use matching area units.

B07.18 **RP Com 07 / Bio 09: transect** (F) (H) (T)

Place quadrats at regular intervals along a line across an environmental gradient to investigate distribution.



B07.19 **RP Com 07 / Bio 09: interpreting patterns** (F) (H) (T)
 Measure the proposed factor at each location; association with abundance suggests a relationship but does not alone prove causation.

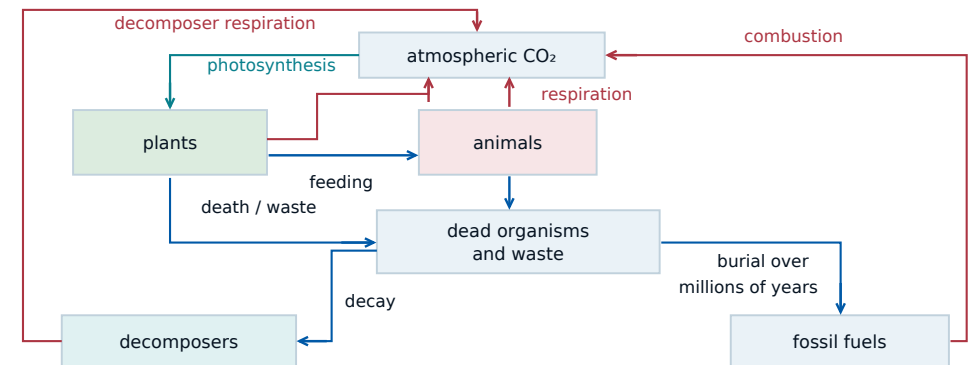
Cycles

B07.20 **Decomposers** (F) (H) (T)
 Microorganisms break down dead material and waste, returning mineral ions to soil and releasing CO₂ by respiration.

Cycles

B07.21 **Carbon cycle** (F) (H) (T)

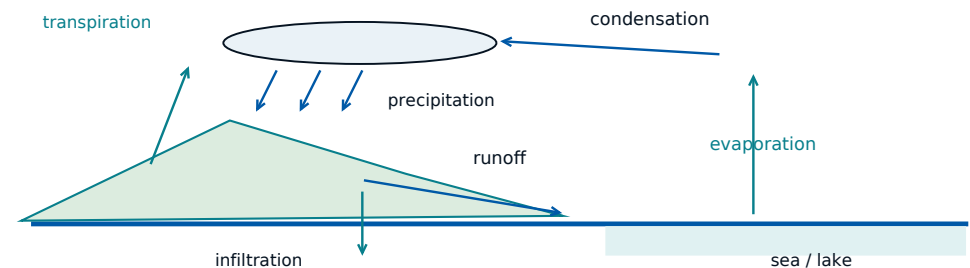
Photosynthesis removes atmospheric CO₂; feeding transfers carbon; respiration, decomposition and combustion return CO₂.



Carbon is recycled through organisms, the atmosphere and long-term stores.

B07.22 **Water cycle** (F) (H) (T)

Evaporation and transpiration → condensation → precipitation → runoff/infiltration; water returns to rivers and seas.



Decomposition and environmental change

B07.T01 **Factors affecting decay** (T)
 Decomposers need water and suitable temperatures for enzymes. Oxygen supports aerobic respiration; higher temperature speeds decay until enzymes become damaged.

B07.T02 **Compost and biogas** (T)
 Warm, moist, aerated conditions encourage compost production. Anaerobic decomposition can produce methane, collected as fuel in a biogas generator.

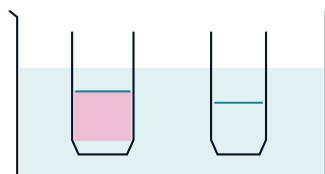
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Decomposition and environmental change

B07.T03 Lipase Method T

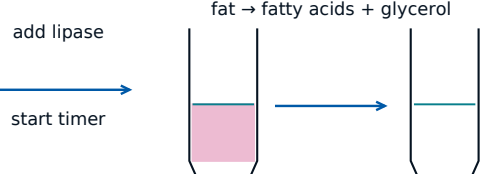
RP Bio 10. Mix 5 cm³ milk, 7 cm³ sodium carbonate and five drops of phenolphthalein. Equilibrate this pink mixture and lipase separately in a water bath. Add 1 cm³ lipase, start timing and stir. Record when pink disappears. Repeat at several temperatures; calculate mean time and relative rate = 1/time. Keep volumes, concentrations, milk and initial pH constant. Wear eye protection; use water baths, away from flames.

1 Equilibrate separately



milk + indicator
+ carbonate
water bath at chosen temperature

2 Stir and time



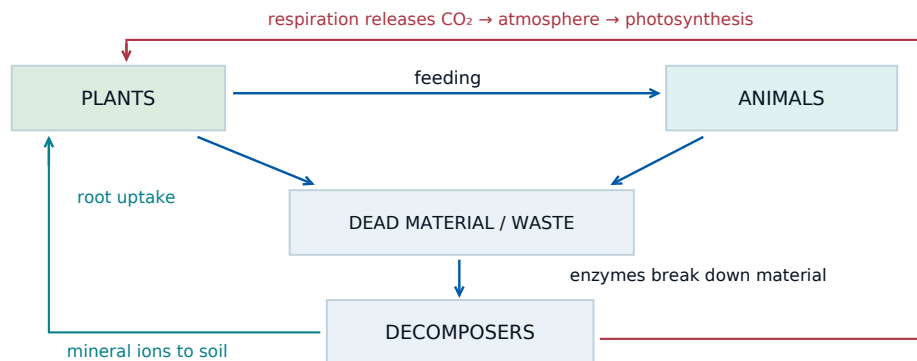
fat → fatty acids + glycerol
pink
colourless
Compare mean times; relative rate = 1/time.

B07.R01 T
Why the lipase endpoint changes

Lipase hydrolyses milk fat to fatty acids and glycerol. Acids lower pH, turning phenolphthalein colourless. This models enzyme action in decay. Increasing temperature increases rate up to an optimum; high temperatures denature the enzyme. A shorter time means a higher relative rate.

B07.R02 Decay cycle F H T

Dead organisms and waste are broken down by decomposers. Mineral ions return to soil and are absorbed by plant roots; feeding passes material to animals. Decomposers respire, returning CO₂ to the air; plants use CO₂ in photosynthesis. Matter cycles, while energy is transferred and dissipated.



Decomposition and environmental change

B07.T04 T

RP Bio 10: rate and reliability

Repeat each temperature at least three times with fresh mixtures and calculate mean time. Compare 1/mean time for the same colour endpoint. Use the same milk, reagent volumes and concentrations, and starting pH. Keep the water-bath temperature steady; mix consistently and judge the endpoint against a white background.

B07.T05 T

Changing distributions

Temperature, water supply and atmospheric gases can change where species survive. Compare seasonal, geographical and human effects with data; correlation alone does not establish a cause.

Biodiversity and people

B07.23

Biodiversity F H T

The variety of species in an ecosystem or on Earth. More diverse ecosystems are often less dependent on any one species.

B07.24

Resource demand F H T

Population growth and higher living standards increase resource use and waste production.

B07.25

Pollution sources F H T

Water: sewage, fertilisers and toxic chemicals. Air: smoke and acidic gases. Land: landfill and toxic chemicals. Pollution can reduce biodiversity.

B07.26

Habitat loss F H T

Building, quarrying, agriculture and waste disposal reduce habitat available to other species.

B07.27

Peat destruction F H T

Removes a distinctive habitat; draining, decay or burning releases stored carbon as CO₂.

B07.28

Deforestation drivers F H T

Land for cattle, rice cultivation and crops for biofuels; loss of trees reduces habitat and carbon storage.

B07.29

Climate effects on ecosystems F H T

Warming can change species distributions, migration, breeding and food availability, increasing extinction risk. The greenhouse mechanism is in C09.

B07.30

Conservation methods F H T

Protect/restore habitats, breed endangered species, maintain hedgerows/field margins, reduce deforestation/emissions and recycle resources.

B07.31

Conservation conflicts F H T

Protection can compete with land, food, housing or income needs; evaluate both ecological and human consequences.

Trophic levels and biomass

B07.T06 T

Numbered trophic levels

Level 1: producers. Level 2: primary consumers. Level 3: secondary consumers. Level 4: tertiary consumers. An apex predator has no predators in its food web.

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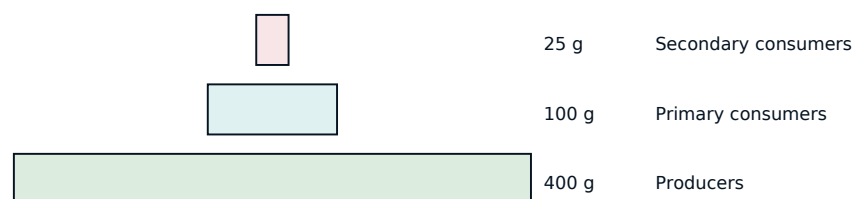
Trophic levels and biomass

B07.T07 **Decomposer feeding** Ⓣ
Enzymes are secreted onto dead material, breaking large molecules into small soluble molecules that diffuse into the decomposer.

B07.T08 **Biomass pyramid** Ⓣ

Horizontal bar width represents biomass at each trophic level, using one scale. Put producers at the base; higher levels normally contain less biomass.

BAR WIDTH $\propto$ BIOMASS



Bar widths are to scale. Each transfer here is 25%; real ecosystems vary.

B07.T09 **Light and biomass transfer** Ⓣ
Producers typically capture about 1% of incident light energy for photosynthesis. Roughly 10% of biomass passes from one trophic level to the next; actual values vary.

B07.T10 **Why biomass decreases** Ⓣ
Not all organisms or parts are eaten; not all eaten material is absorbed. Respiration releases carbon dioxide and water; excretion removes water and urea, reducing material available for new biomass.

B07.T11 **Biomass transfer efficiency** Ⓣ
 $100 \times \text{biomass gained at the next level} \div \text{biomass available at the previous level}$, using matching mass units. Limited transfer restricts the biomass and often the number of top predators.

Food production

B07.T12 **Food security** Ⓣ
Reliable access to enough food for a population. Population growth, changing diets, pests, disease, drought, input costs and conflict can threaten supply.

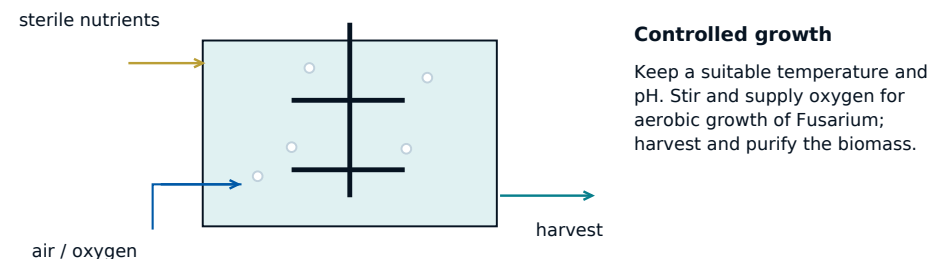
B07.T13 **Efficient animal farming** Ⓣ
Limiting movement and maintaining a suitable warm environment reduce respiration demands; protein-rich feed supports growth. Evaluate yield against costs, resource use and animal welfare.

B07.T14 **Sustainable fisheries** Ⓣ
Quotas limit catches; suitable mesh sizes allow small fish to escape and reproduce. Maintaining breeding populations helps stocks recover.

Food production

B07.T15 **Mycoprotein** Ⓣ

Fusarium fungus is grown on glucose syrup with oxygen and suitable controlled conditions. Its biomass is harvested and purified into a protein-rich food.



B07.T16 **Biotechnology and supply** Ⓣ
GM crops can improve yield or nutrition, as in golden rice. Genetically modified bacteria produce human insulin; the genetic-engineering process has its home in earlier B06 rows.

C01 | Atomic structure and the periodic table

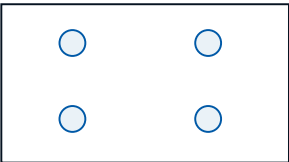
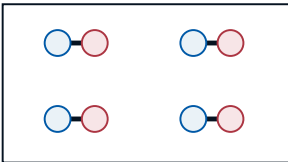
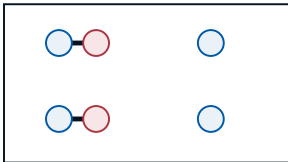
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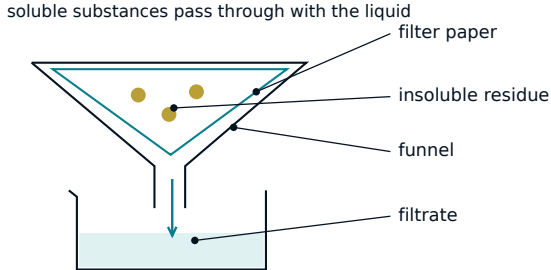
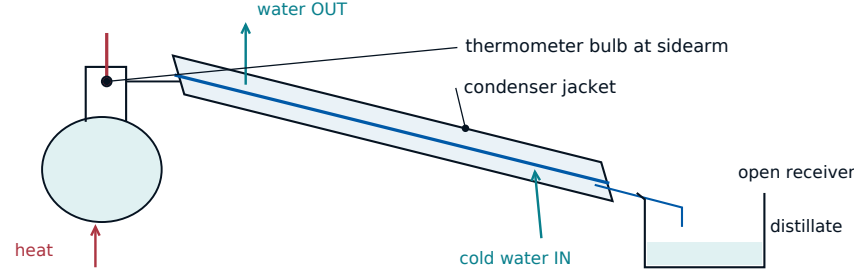
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Elements and separation

C01.01 Atom	(F)(H)(T)	The smallest part of an element that can exist.
C01.02 Element	(F)(H)(T)	A substance containing only one type of atom, identified by its proton number.
C01.03 Compound	(F)(H)(T)	Two or more elements chemically bonded in fixed proportions; chemical reactions are needed to separate them.
C01.04 Mixture	(F)(H)(T)	Two or more substances together without chemical bonding between them; they can be separated physically.
ELEMENT  one atom type COMPOUND  different atoms bonded MIXTURE  substances together		
C01.05 Chemical formula	(F)(H)(T)	Shows which elements are present and their atom ratio. A subscript counts atoms; a coefficient multiplies the whole formula.
C01.06 First 20 elements: 1-10	(F)(H)(T)	H hydrogen; He helium; Li lithium; Be beryllium; B boron; C carbon; N nitrogen; O oxygen; F fluorine; Ne neon.
C01.07 First 20 elements: 11-20	(F)(H)(T)	Na sodium; Mg magnesium; Al aluminium; Si silicon; P phosphorus; S sulfur; Cl chlorine; Ar argon; K potassium; Ca calcium.

Elements and separation

C01.08 Filtration	(F)(H)(T)	Separates an insoluble solid (residue) from a liquid (filtrate) using a filter.
soluble substances pass through with the liquid 		
C01.09 Crystallisation	(F)(H)(T)	Concentrate a solution by evaporating some solvent, then cool so dissolved solute forms crystals.
C01.10 Simple distillation	(F)(H)(T)	Evaporate a liquid, then condense its vapour to collect it separately from dissolved solids.
		
C01.11 Fractional distillation	(F)(H)(T)	Separates liquids with different boiling points by repeated evaporation and condensation; the crude-oil context is in C07.
C01.12 Chromatography	(F)(H)(T)	The full separation principle, diagram and R _f definition have their home in C08.

The atom and its history

C01.13 Proton	(F)(H)(T)	In the nucleus; relative charge +1 and relative mass 1.
C01.14 Neutron	(F)(H)(T)	In the nucleus; charge 0 and relative mass 1.

C01 | Atomic structure and the periodic table

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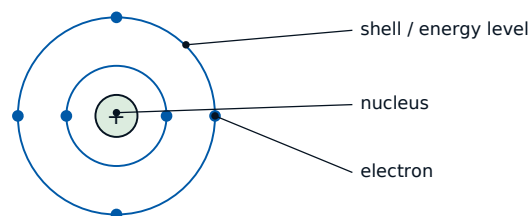
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The atom and its history

C01.15 Electron

(F)(H)(T)

In shells/energy levels around the nucleus; relative charge -1 and very small relative mass (about $1/1836$).



carbon atom shown: 2,4 electron arrangement; not to scale

C01.16 Atomic number, Z

(F)(H)(T)

Number of protons; equals electron number in a neutral atom.

C01.17 Mass number, A

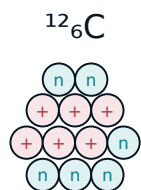
(F)(H)(T)

Mass number $A = \text{protons} + \text{neutrons}$. Neutrons $= A - Z$: in isotope notation, take the bottom number (atomic number) away from the top number (mass number). Example: $^{14}_6\text{C}$ has $14 - 6 = 8$ neutrons.

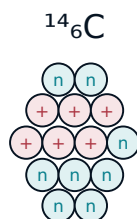
C01.18 Isotope

(F)(H)(T)

Atoms of the same element with equal proton numbers but different neutron numbers.



6 protons; 6 neutrons



6 protons; 8 neutrons

Same element

Same proton number; different neutron number and mass number. Nuclei only: electrons are omitted.

C01.19 Atom scale

(F)(H)(T)

Typical radius $\approx 1 \times 10^{-10}$ m; nucleus radius $\approx 1 \times 10^{-14}$ m. Nearly all atomic mass is in the tiny nucleus.

C01.20 Ion

(F)(H)(T)

A charged particle formed by gaining or losing electrons; proton number is unchanged. Losing electrons forms a positive ion.

C01.21 Relative atomic mass, A_r

(F)(H)(T)

An abundance-weighted mean mass of an element's atoms relative to $1/12$ of carbon-12's mass.

The atom and its history

C01.22 Isotope-average rule

(F)(H)(T)

$A_r = \text{sum of (isotope mass} \times \text{percentage abundance)} \div 100$. It has no unit.

C01.23 Electronic structure

(F)(H)(T)

Electrons fill lowest available energy levels first. For the first 20 elements, the GCSE shell pattern fills 2, then 8, then 8.

C01.24 Early atom models

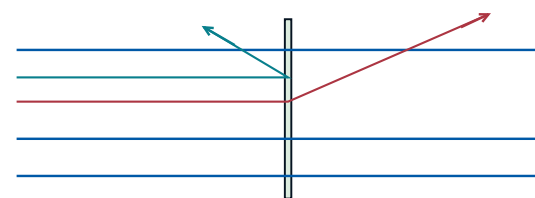
(F)(H)(T)

Dalton: indivisible spheres. Thomson's electron discovery led to a positive sphere containing negative electrons (plum pudding).

C01.25 Alpha-scattering evidence

(F)(H)(T)

Most alpha particles passed through foil: mainly empty space. A few deflected strongly/backwards: tiny, dense, positively charged nucleus.



thin gold foil

From paths to structure

Most pass: mainly empty space. A few strongly deflect: mass and positive charge concentrated in a tiny nucleus. Deflection proportions are exaggerated.

C01.26 Bohr and Chadwick

(F)(H)(T)

Bohr proposed fixed electron energy levels; Chadwick supplied evidence for neutrons in the nucleus.

Periodic patterns

C01.27 Periodic table order

(F)(H)(T)

Increasing atomic number; columns are groups and rows are periods.

	1	2		3	4	5	6	7	0
1	H								He
2	Li	Be							
3	Na	Mg							
4	K	Ca							

Group labels above; period numbers at left. First 20 elements only; gaps are intentional.

C01.28 Group and period

(F)(H)(T)

For main-group elements, outer electrons explain group properties; the period gives the number of occupied shells.

C01 | Atomic structure and the periodic table

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Periodic patterns		
C01.29 Mendeleev's table	ⓕ ⓗ Ⓣ	Used atomic weights and chemical properties; left gaps and predicted undiscovered elements. Later discoveries supported his arrangement.
C01.30 Why mass order differs	ⓕ ⓗ Ⓣ	Isotopes explain why relative atomic mass order does not always match atomic-number order.
C01.31 Metals and non-metals	ⓕ ⓗ Ⓣ	Metals tend to lose electrons and form positive ions; non-metals tend to gain/share electrons. Metals occupy most of the left/centre of the table.
Groups 0, 1 and 7		
C01.32 Group 0	ⓕ ⓗ Ⓣ	Noble gases have full outer shells: 8 electrons, except helium with 2; very unreactive and monatomic. Boiling points increase down the group.
C01.33 Group 1	ⓕ ⓗ Ⓣ	Alkali metals have one outer electron and form +1 ions. Reactivity increases down the group because the outer electron is lost more easily.
C01.34 Alkali metals with water	ⓕ ⓗ Ⓣ	Metal + water → metal hydroxide + hydrogen; lithium, sodium and potassium react increasingly vigorously.
C01.35 Alkali metals with oxygen/chlorine	ⓕ ⓗ Ⓣ	They form metal oxides with oxygen and metal chlorides with chlorine.
C01.36 Group 7	ⓕ ⓗ Ⓣ	Halogens have seven outer electrons; form –1 ions with metals and exist as diatomic molecules such as Cl ₂ .
C01.37 Halogen trends	ⓕ ⓗ Ⓣ	Down the group, melting/boiling points increase but reactivity decreases: attracting an extra electron becomes harder.
C01.38 Halogens with other elements	ⓕ ⓗ Ⓣ	With metals they form ionic halides; with non-metals they form covalent compounds.
C01.39 Halogen displacement	ⓕ ⓗ Ⓣ	A more reactive halogen displaces a less reactive one from an aqueous halide salt: chlorine displaces bromine and iodine.
C01.40 Halogen appearances	ⓕ ⓗ Ⓣ	Chlorine: green gas; bromine: red-brown liquid; iodine: grey solid that forms purple vapour.

Transition metals		
C01.T01 Transition metals versus Group 1	Ⓣ	Usually denser, stronger and harder, with higher melting points and lower reactivity with oxygen, water and halogens. Examples include chromium, manganese, iron, cobalt, nickel and copper.
C01.T02 Transition-metal compounds	Ⓣ	Many form coloured compounds and ions with different charges, such as Fe ²⁺ and Fe ³⁺ . Group 1 metals form +1 ions and generally colourless compounds.
C01.T03 Transition-metal catalysts	Ⓣ	Iron catalyses the Haber process; nickel catalyses hydrogenation; manganese dioxide catalyses hydrogen peroxide decomposition. Copper compounds are often blue/green; many chromium compounds are coloured.

C02 | Bonding, structure and properties

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Bonding models		
C02.01	(F)(H)(T)	Strong electrostatic attraction between oppositely charged ions; a metal transfers electrons to a non-metal.
Ionic bond		
C02.02	(F)(H)(T)	Group 1: +1; Group 2: +2; Group 6: -2; Group 7: -1. Ions commonly gain a full outer shell.
Common ion charges		
C02.03	(F)(H)(T)	Ionic dot-and-cross diagram
Show transferred electrons, full outer shells, brackets and charges; different marks show electron origins.		
× sodium electrons; • chlorine electrons. Outer shells only. Full outer shells Na⁺ loses its original outer shell. Cl⁻ gains one electron from Na. Brackets and charges identify the ions.		
C02.04	(F)(H)(T)	The simplest whole-number ion ratio giving zero total charge; for example MgCl ₂ has one Mg ²⁺ for two Cl ⁻ .
Ionic formula		
C02.05	(F)(H)(T)	Giant ionic lattice
A regular repeating structure with attractions in every direction; sodium chloride is not made of separate NaCl molecules.		
Giant ionic lattice Alternating positive and negative ions. Strong attractions act in every direction; this is a 2D slice through a 3D structure.		
C02.06	(F)(H)(T)	A shared pair of electrons between atoms; a strong bond.
Covalent bond		

Bonding models		
C02.07	(F)(H)(T)	Show shared pairs and all non-bonding outer electrons. Single, double and triple bonds have one, two and three shared pairs.
Covalent dot-and-cross diagram		
C02.08	(F)(H)(T)	Hydrogen / chlorine bonds
H ₂ and Cl ₂ each have one shared electron pair; chlorine also has three lone pairs on each atom.		
One shared pair gives one bond. Shell circles show the overlap.		
C02.09	(F)(H)(T)	Hydrogen chloride bonding
HCl has one shared pair; chlorine has three lone pairs.		
Hydrogen chloride One shared pair; chlorine also has three lone pairs. H has 2 outer electrons; Cl has 8. Overlapping circles show shared electrons in both outer shells.		

C02 | Bonding, structure and properties

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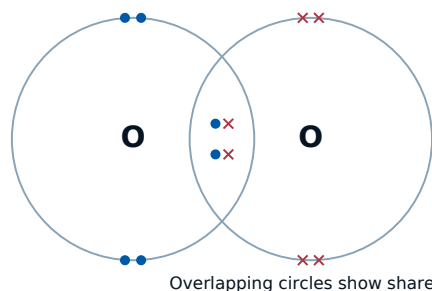
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Bonding models

C02.10 Oxygen bonding

(F) (H) (T)

O₂ has a double bond (two shared pairs); each oxygen also has two lone pairs.



Oxygen: double bond

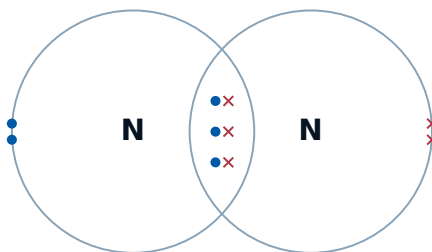
Two shared pairs and two lone pairs per oxygen: 8 outer electrons per atom.

Overlapping circles show shared electrons in both outer shells.

C02.11 Nitrogen bonding

(F) (H) (T)

N₂ has a triple bond (three shared pairs); each nitrogen also has one lone pair.



Nitrogen: triple bond

Three shared pairs and one lone pair per nitrogen: 8 outer electrons per atom.

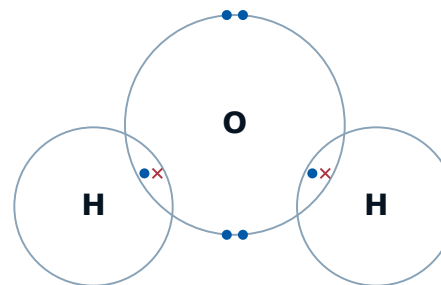
Overlapping circles show shared electrons in both outer shells.

Bonding models

C02.12 Water bonding

(F) (H) (T)

H₂O has two single bonds; oxygen has two lone pairs.



Water

Each H shares one pair with the central atom. H has 2 electrons in its shell; the central atom has 8 in its outer shell.

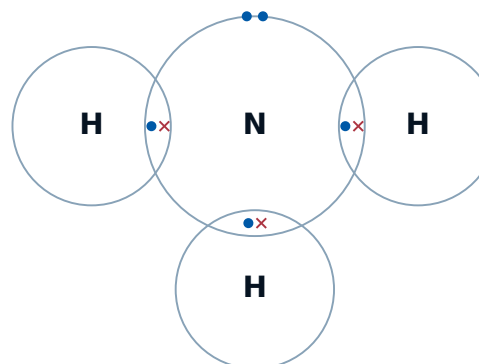
Dots and crosses identify electron origins. The layout shows bonding; it is not the exact 3D molecular shape.

Outer shells are drawn as circles for GCSE.

C02.13 Ammonia bonding

(F) (H) (T)

NH₃ has three single bonds; nitrogen has one lone pair.



Ammonia

Each H shares one pair with the central atom. H has 2 electrons in its shell; the central atom has 8 in its outer shell.

Dots and crosses identify electron origins. The layout shows bonding; it is not the exact 3D molecular shape.

Outer shells are drawn as circles for GCSE.

C02 | Bonding, structure and properties

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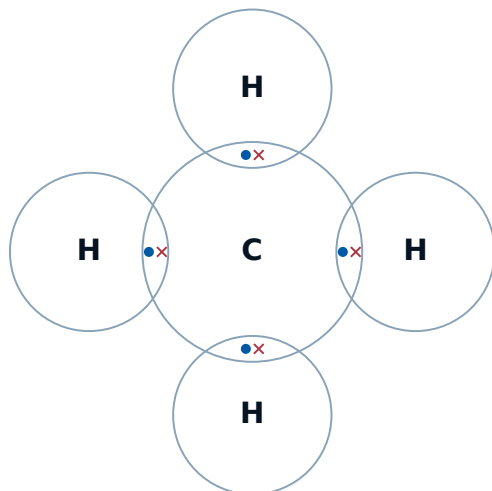
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Bonding models

C02.14 Methane bonding

(F) (H) (T)

CH₄ has four single bonds around carbon; carbon has no lone pair.



Methane

Each H shares one pair with the central atom. H has 2 electrons in its shell; the central atom has 8 in its outer shell.

Dots and crosses identify electron origins. The layout shows bonding; it is not the exact 3D molecular shape.

Outer shells are drawn as circles for GCSE.

C02.15 Displayed formula

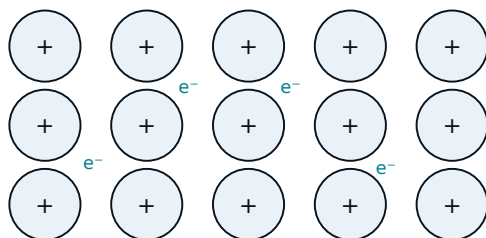
(F) (H) (T)

A line represents one shared pair of electrons; it shows bonds but not lone pairs.

C02.16 Metallic bonding

(F) (H) (T)

Strong attraction between positive metal ions and delocalised electrons moving throughout a giant structure.



Metallic bonding

Positive metal ions attract delocalised electrons. Mobile electrons carry charge through the giant structure.

C02.17 Model limitations

(F) (H) (T)

Diagrams may not show true sizes, distances or 3D arrangement. Sticks are representations of bonds, not physical rods.

States and structure-property links

C02.18 State symbols

(F) (H) (T)

(s) solid; (l) liquid; (g) gas; (aq) dissolved in water. Particle arrangements and changes of state have their home in P03.

C02.19 Melting and boiling points

(F) (H) (T)

Stronger attractions between particles require more energy to overcome, usually giving higher transition temperatures.

C02.20 Particle-model limits

(H) (T)

Solid-sphere models omit attractions, internal structure and deformability; atoms do not themselves have bulk properties such as melting point.

C02.21 Ionic melting points

(F) (H) (T)

High: many strong electrostatic attractions must be overcome.

C02.22 Ionic conduction

(F) (H) (T)

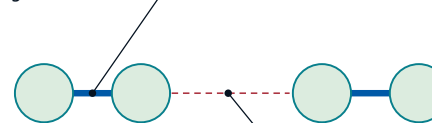
Solid: ions fixed, so no conduction. Molten or dissolved: ions move and carry charge.

C02.23 Small-molecule melting points

(F) (H) (T)

Usually low: weak intermolecular forces are overcome; the covalent bonds within molecules remain intact.

strong covalent bond



weak intermolecular force

During boiling

Molecules separate as intermolecular forces are overcome. The covalent bonds within each molecule remain intact.

C02.24 Molecule size trend

(F) (H) (T)

Larger molecules generally have stronger intermolecular forces and higher melting/boiling points.

C02.25 Small-molecule conduction

(F) (H) (T)

No mobile charged particles, so these substances usually do not conduct electricity.

C02.26 Polymer

(F) (H) (T)

A very large molecule built from repeating units joined by covalent bonds. Stronger intermolecular attractions make many polymers solid at room temperature.

C02.27 Giant covalent structure

(F) (H) (T)

An extensive network of strong covalent bonds; a very high melting point because many bonds must be broken.

C02 | Bonding, structure and properties

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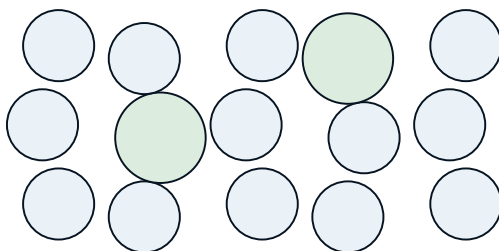
States and structure-property links

C02.28 **Metal properties** (F) (H) (T) Strong metallic bonding usually gives high melting/boiling points. Delocalised electrons conduct electricity and transfer thermal energy.

C02.29 **Pure-metal malleability** (F) (H) (T) Regular layers of atoms can slide while metallic bonding is maintained.

C02.30 **Alloy hardness** (F) (H) (T)

Different-sized atoms distort the layers, making sliding harder than in a pure metal.



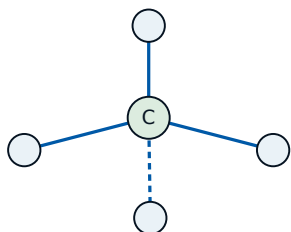
Distorted layers

Different-sized atoms disrupt the regular layers. They cannot slide as easily as the layers in a pure metal.

Carbon structures

C02.31 **Diamond** (F) (H) (T)

Each carbon bonds to four others in a rigid network: very hard, very high melting point, no delocalised electrons to conduct.



local 3D structure; not a separate molecule

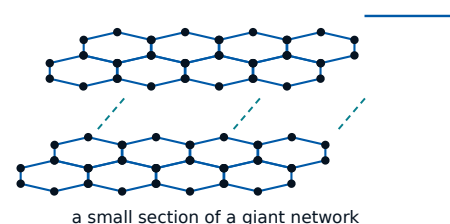
Four strong bonds per carbon

Tetrahedral 3D arrangement continues throughout the giant network. No delocalised electrons; very hard and does not conduct electricity.

Carbon structures

C02.32 **Graphite** (F) (H) (T)

Each carbon bonds to three others in layers of hexagons. Weak attractions between layers allow sliding; delocalised electrons conduct.

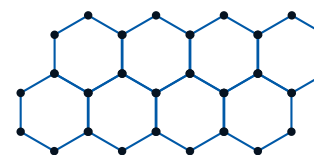


Many stacked layers

Strong covalent bonds within layers; weak attractions between layers allow sliding. Delocalised electrons conduct.

C02.33 **Graphene** (F) (H) (T)

One layer of graphite; thin, strong and electrically conducting, useful in electronics and composites.



a small section of a giant network

One atom thick

One sheet of carbon atoms in hexagons. Each carbon bonds to three others; delocalised electrons can carry charge.

C02.34 **Fullerene** (F) (H) (T) A hollow carbon molecule made of rings; may form cages or tubes. Buckminsterfullerene is C₆₀.

C02.35 **Carbon nanotube** (F) (H) (T) A cylindrical fullerene with high length-to-diameter ratio; strong and conducting, useful for reinforced materials and electronics.

C02.36 **Fullerene uses** (F) (H) (T) Their structures can suit drug delivery, lubricants and catalysts; nanotubes also reinforce materials.

Nanoparticles

C02.T01 **Particle size ranges** (T) Nanoparticles: 1-100 nm. Fine particles: 100-2500 nm. Coarse particles (dust): about 2500-10 000 nm. A typical atom is about 0.1 nm across.

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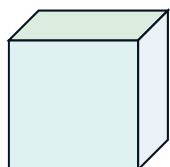
Nanoparticles

C02.T02 Surface area and size



For a cube of side a , surface area = $6a^2$ and volume = a^3 , so $SA:V = 6/a$. Reducing side length tenfold increases the ratio tenfold.

side 10 units



$$SA:V = 0.6$$

side 1 unit



$$SA:V = 6$$

Tenfold smaller side

Tenfold larger surface area : volume ratio. Both cubes use the same drawing scale.

C02.T03 Why nanoscale properties differ



A larger proportion of atoms is at the surface. High surface area per mass can make a small quantity effective, for example in catalysis.

C02.T04 Nanoparticle applications



Uses include targeted medicines, electronics, cosmetics, sun creams, deodorants and catalysts. Match the stated property to the intended use when evaluating an example.

C02.T05 Nanoparticle risks



Small particles may enter cells or the body differently from bulk material. Health and environmental effects require evidence; weigh exposure and uncertainty against the benefit.

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Mass and formulae

C03.01 Conservation of mass

(F) (H) (T)

Atoms are rearranged, not created or destroyed, in a chemical reaction; total mass is conserved in a closed system.



4 H atoms + 2 O atoms on each side



C03.02 Balanced equation

(F) (H) (T)

Equal numbers of each element's atoms on both sides. Change coefficients, never the subscripts in correct formulae.

C03.03 Relative formula mass, M_r

(F) (H) (T)

Sum of the A_r values of all atoms in a formula; no unit.

C03.04 Percentage by mass

(F) (H) (T)

$100 \times \text{total } A_r \text{ contribution of the chosen element} \div M_r \text{ of the compound.}$

C03.05 Apparent mass gain

(F) (H) (T)

A gas from the surroundings has joined the reactants, as when a metal gains oxygen.

C03.06 Apparent mass loss

(F) (H) (T)

A gaseous product escapes an open container; total mass, including escaped gas, is still conserved.

C03.07 Measurement uncertainty

(F) (H) (T)

Every measured value has a range of possible values; the spread of repeats helps estimate uncertainty. General data vocabulary is in the shared reference sheet.

Amounts and concentrations

C03.08 Mole

(H) (T)

The amount containing 6.02×10^{23} specified particles (Avogadro constant); unit mol.

C03.09 Molar mass

(H) (T)

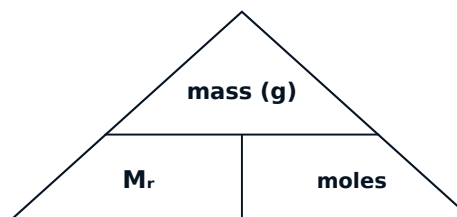
Mass of one mole in g/mol; numerically equal to A_r or M_r .

Amounts and concentrations

C03.10 Mass, M_r and moles

(H) (T)

Moles (mol) = mass (g) $\div$ M_r ; mass (g) = $M_r \times$ moles (mol). M_r is relative formula mass (relative molecular mass for molecules) and has no unit. Its numerical value equals molar mass in g/mol. For single atoms, use A_r instead.



For single atoms, use A_r (relative atomic mass).

$$\text{mass} = M_r \times \text{moles}$$

$$\text{moles} = \text{mass} \div M_r$$

M_r : relative formula mass; no unit. Its value equals molar mass in g/mol. Use grams and moles.

C03.11 Calculating particle number

(H) (T)

Number of particles = number of moles $\times 6.02 \times 10^{23}$. Example: 2 mol contains 1.204×10^{24} particles.

C03.12 Using a mole ratio

(H) (T)

Use the big numbers in front of formulae. In $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, 2 mol H_2 reacts with 1 mol O_2 to make 2 mol H_2O . These are mole ratios, not mass ratios.

C03.13 Calculating a reacting mass

(H) (T)

1. Moles = known mass $\div$ M_r .
2. Use the mole ratio in the balanced equation to find the moles you need.
3. Required mass = those moles $\times M_r$.

C03.14 Ratios from masses

(H) (T)

Divide each mass by its molar mass, then simplify the mole amounts to a whole-number ratio to balance an equation.

C03.15 Limiting reactant

(H) (T)

The reactant used up first; it sets the maximum amount of product. Other reactants are in excess.



excess H_2 remains

O_2 is used up first



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Amounts and concentrations		
C03.16	(F) (H) (T)	Concentration (g/dm ³) = dissolved-solute mass (g) ÷ solution volume (dm ³).
Mass concentration		
C03.17	(F) (H) (T)	1 dm ³ = 1000 cm ³ ; divide cm ³ by 1000 before using a g/dm ³ concentration.
Volume conversion		
C03.18	(H) (T)	At fixed volume, more solute means greater concentration; at fixed solute mass, greater solution volume means lower concentration.
Concentration relationships		
Yield and atom economy		
C03.T01	(T)	100 × actual product mass ÷ theoretical maximum product mass. Use the same mass units; the theoretical value comes from the balanced reaction.
Percentage yield		
C03.T02	(T)	A reversible reaction may not finish; material may be lost during separation; reactants may form unwanted products. An apparent yield above 100% can indicate wet or impure product.
Why yield is below 100%		
C03.T03	(T)	Convert reactant mass to moles, use the balanced coefficient ratio, then multiply product moles by its molar mass. Use the limiting reactant if several are given.
Theoretical yield		
C03.T04		(T)
Atom economy		
100 × total Mr of the desired product from the balanced equation ÷ total Mr of all reactants from that equation. Include coefficients.		
CaCO₃ → CaO + CO₂ Reactants: 100 → CaO: 56 CO₂: 44 Desired product: CaO Atom economy = 56 ÷ 100 × 100 = 56%. Bar widths represent relative masses.		
C03.T05	(T)	Yield compares what was collected with what could be made. Atom economy measures how much of the reactant mass can enter the desired product; it follows from the reaction equation.
Yield versus atom economy		
C03.T06	(T)	Compare atom economy, actual yield, rate, equilibrium, energy and raw-material costs, and whether by-products have useful markets. No single percentage decides every choice.
Choosing a pathway		

Molar concentrations and gas volumes		
C03.T07		(T)
Molar concentration		
c = n/V, with c in mol/dm ³ , n in mol and V in dm ³ . Convert cm ³ to dm ³ by dividing by 1000 before substitution.		
Volume 25.0 cm³ → Divide by 1000 0.0250 dm³ → n = cV 0.200 mol/dm³ × 0.0250 dm³ = 0.00500 mol Choose consistent units first; 25 cm³ is not 25 dm³.		
C03.T08	(T)	Concentration in g/dm ³ = concentration in mol/dm ³ × molar mass in g/mol. Divide by molar mass for the reverse conversion.
Converting concentration		
C03.T09	(T)	Find moles of the known solution using cV, apply the balanced mole ratio, then divide the unknown moles by its volume in dm ³ . The volumes alone do not imply a 1:1 ratio.
Titration calculation		
C03.T10	(T)	At room temperature and pressure (20°C, 1 atmosphere), 1 mol of gas occupies 24 dm ³ . V = 24n when V is in dm ³ under these conditions.
Gas molar volume		
C03.T11	(T)	At the same temperature and pressure, gas volumes follow the balanced coefficients. N ₂ + 3H ₂ → 2NH ₃ gives a 1:3:2 gas-volume ratio if conversion is complete.
Gas-volume ratios		
C03.T12	(T)	Use n = mass ÷ molar mass, then V = 24n at room temperature and pressure. Example: 4.4 g CO ₂ ÷ 44 g/mol = 0.10 mol, occupying 2.4 dm ³ .
Mass to gas volume		

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Metals and redox														
C04.01 Oxidation / reduction (oxygen) (F)(H)(T)	Oxidation is gain of oxygen; reduction is loss of oxygen.													
C04.02 Metal + oxygen (F)(H)(T)	Produces a metal oxide; the metal is oxidised.													
C04.03 Reactivity series (F)(H)(T)														
Most to least: potassium, sodium, lithium, calcium, magnesium, aluminium, carbon, zinc, iron, hydrogen, copper, silver, gold. Carbon and hydrogen are comparison points.														
← increasing reactivity → <table><tr><td>K</td><td>Na</td><td>Li</td><td>Ca</td><td>Mg</td><td>Al</td><td>C</td><td>Zn</td><td>Fe</td><td>H</td><td>Cu</td><td>Ag</td><td>Au</td></tr></table> below carbon: carbon reduction possible above hydrogen: suitable metals can release H₂ from dilute acids Carbon and hydrogen are comparison points, not metals.		K	Na	Li	Ca	Mg	Al	C	Zn	Fe	H	Cu	Ag	Au
K	Na	Li	Ca	Mg	Al	C	Zn	Fe	H	Cu	Ag	Au		
C04.04 Reactivity and ions (F)(H)(T)	A more reactive metal forms positive ions more readily.													
C04.05 Cold water reactions (F)(H)(T)	K, Na and Li react vigorously; Ca reacts less vigorously; Mg reacts very slowly. Zn, Fe and Cu show no appreciable reaction with cold water.													
C04.06 Dilute-acid reactions (F)(H)(T)	Mg, Zn and Fe react with dilute hydrochloric/sulfuric acid to give salt and hydrogen; Cu does not. More reactive metals react faster under comparable conditions.													

Metals and redox	
C04.07 Metal displacement (F) (H) (T)	A more reactive metal displaces a less reactive metal from its compound. Magnesium + copper sulfate → magnesium sulfate + copper. $\text{Mg(s)} + \text{CuSO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{Cu(s)}$. Copper cannot displace magnesium from magnesium sulfate. magnesium copper sulfate reaction copper forms More reactive replaces less reactive Magnesium goes into solution as ions. Copper metal forms; the blue solution fades. No reaction for the reverse combination. Mg + CuSO₄ → MgSO₄ + Cu
C04.08 Metal extraction (F) (H) (T)	Metals below carbon can be extracted from oxides using carbon reduction. Very unreactive metals can occur naturally as the element.
C04.09 Electron redox (H) (T)	OIL RIG: Oxidation Is Loss of electrons; Reduction Is Gain of electrons. A species is an atom, molecule or ion. Identify the species that loses or gains electrons, not a spectator ion.
C04.10 Displacement ionic equation (H) (T)	$\text{Mg(s)} + \text{Cu}^{2+}\text{(aq)} \rightarrow \text{Mg}^{2+}\text{(aq)} + \text{Cu(s)}$. Magnesium atoms lose two electrons and are oxidised; copper(II) ions gain two electrons and are reduced. Sulfate ions are spectators. BALANCED $\text{Mg(s)} + \text{CuSO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{Cu(s)}$ SPLIT IONS $\text{Mg(s)} + \text{Cu}^{2+}\text{(aq)} + \text{SO}_4^{2-}\text{(aq)} \rightarrow \text{Mg}^{2+}\text{(aq)} + \text{SO}_4^{2-}\text{(aq)} + \text{Cu(s)}$ CANCEL Remove SO_4^{2-}: identical ions on both sides. NET IONIC $\text{Mg(s)} + \text{Cu}^{2+}\text{(aq)} \rightarrow \text{Mg}^{2+}\text{(aq)} + \text{Cu(s)}$ Atoms conserved. Total charge: +2 on each side.
C04.R01 Writing an ionic equation (H) (T)	1 Balance the symbol equation and add state symbols. 2 Split aqueous soluble ionic substances into their ions, preserving coefficients. 3 Keep solids, liquids, gases and undissociated molecules intact. 4 Cancel identical spectator ions on both sides. 5 Check atoms and total charge.

C04 | Chemical changes

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Metals and redox		
C04.R02	(H) (T)	Subscripts belong to the chemical formula; coefficients multiply whole particles. $\text{CuCl}_2(\text{aq})$ gives $\text{Cu}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$. The ions have total charge $+2 + 2(-1) = 0$. Do not write CuCl_2 as $\text{Cu}^{+} + \text{Cl}_2^{-}$.
C04.R03		Balancing a displacement (H) (T)
$\text{Al}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Al}^{3+}(\text{aq}) + \text{Cu}(\text{s})$. Balance electron transfer using 2 Al atoms and 3 Cu^{2+} ions: $2\text{Al}(\text{s}) + 3\text{Cu}^{2+}(\text{aq}) \rightarrow 2\text{Al}^{3+}(\text{aq}) + 3\text{Cu}(\text{s})$. Total charge is +6 on both sides.		
$2\text{Al} \rightarrow 2\text{Al}^{3+} + 6\text{e}^{-}$ oxidation: six electrons lost $3\text{Cu}^{2+} + 6\text{e}^{-} \rightarrow 3\text{Cu}$ reduction: six electrons gained $2\text{Al}(\text{s}) + 3\text{Cu}^{2+}(\text{aq}) \rightarrow 2\text{Al}^{3+}(\text{aq}) + 3\text{Cu}(\text{s})$ 2 Al and 3 Cu on each side; charge +6 on each side.		
C04.R04	(H) (T)	Al $\rightarrow \text{Al}^{3+} + 3\text{e}^{-}$ and $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}$. Multiply the first by 2 and the second by 3 so both involve six electrons. Add the equations, then cancel electrons. A complete ionic equation has no leftover electrons.
C04.R05	(H) (T)	Balance $\rightarrow$ convert known mass to moles $\rightarrow$ apply the coefficient ratio $\rightarrow$ convert required moles to mass. Use $n = \text{mass}/M_r$ (or A_r for a metal). Coefficients give a mole ratio, not a mass ratio. Check which reactant is limiting.
C04.R06	(H) (T)	For 0.48 g Mg reacting with excess CuSO_4 : $n(\text{Mg}) = 0.48/24 = 0.020$ mol. Mg:Cu is 1:1, so $n(\text{Cu}) = 0.020$ mol. Copper mass = $0.020 \times 63.5 = 1.27$ g (1.3 g to 2 significant figures).
Acids, bases and salts		
C04.11	(F) (H) (T)	Acids produce H^{+} ions in aqueous solution.
C04.12	(F) (H) (T)	A base neutralises an acid; an alkali is a soluble base that produces OH^{-} ions in aqueous solution.
C04.13	(F) (H) (T)	Below 7: acidic; 7: neutral; above 7: alkaline. Universal indicator estimates pH; a probe measures it more precisely.
C04.14	(F) (H) (T)	Salt + hydrogen, for a suitable reactive metal.
C04.15	(F) (H) (T)	Salt + water. Bases include metal oxides and hydroxides.

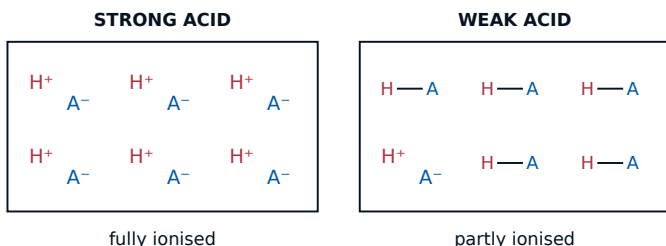
Acids, bases and salts	
C04.16	(F) (H) (T) Salt + water + carbon dioxide.
C04.17	(F) (H) (T) Acid + carbonate Hydrochloric acid $\rightarrow$ chloride; nitric acid $\rightarrow$ nitrate; sulfuric acid $\rightarrow$ sulfate. The metal supplies the first part of the salt's name.
C04.18	(F) (H) (T) Salt names Na^{+} , K^{+} , Mg^{2+} , Ca^{2+} , Cu^{2+} , Al^{3+} ; Cl^{-} , OH^{-} , NO_3^{-} , SO_4^{2-} , CO_3^{2-} . Balance positive and negative charges.
C04.19	(F) (H) (T) Useful ions for salts $\text{H}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$.
C04.R07	(H) (T) Neutralisation ionic equation $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$. Na^{+} and Cl^{-} remain unchanged and cancel. $\text{H}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$: total charge is zero on both sides. There is no electron transfer, so this is not a redox reaction.
C04.20	RP Com 08 / Chem 01: soluble-salt preparation (F) (H) (T)
Warm dilute acid gently; add insoluble oxide/carbonate in excess; filter off unreacted solid; evaporate some water; cool, filter and dry crystals.	
warm acid + excess insoluble solid $\rightarrow$ filter off unreacted solid $\rightarrow$ gently concentrate solution $\rightarrow$ cool to crystallise; filter + dry     Excess solid uses up the acid. Do not evaporate to complete dryness.	
C04.21	(F) (H) (T) RP Com 08 / Chem 01: reasons and precautions Excess solid ensures acid is used up; filtration removes it. Gentle evaporation avoids spitting or decomposition. Use eye protection and a water bath/electric heater for concentration.

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Acids, bases and salts

C04.22 Strong and weak acids (H) (T)

Strong acids ionise completely in water; weak acids ionise only partly. Strength is different from concentration.



Same concentration

Same number of acid particles per volume. Strength describes ionisation, not how dilute the solution is. Water omitted.

C04.23 Acid examples (H) (T)

Strong: hydrochloric, nitric, sulfuric. Weak: ethanoic, citric, carbonic.

C04.24 pH and H⁺ (H) (T)

A fall of one pH unit means ten times greater H⁺ concentration. At the same concentration, a stronger acid usually has lower pH.

C04.25 Metal-acid redox (H) (T)

Metal atoms lose electrons to form ions; hydrogen ions gain electrons to form hydrogen molecules.

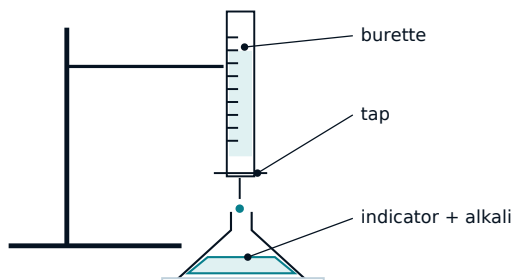
C04.R08 Metal + acid ionic equation (H) (T)

$\text{Mg(s)} + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g})$. $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$ is oxidation; $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ is reduction. Chloride or sulfate ions from the acid are spectators.

Titrations

C04.T01 RP Chem 02: titration setup (T)

Use a pipette and filler for a fixed alkali volume in a conical flask. Add a few drops of a suitable indicator; deliver acid from a burette while swirling over a white tile.



Read the meniscus

Use the bottom of the curve at eye level. Add dropwise near the endpoint; swirl over a white tile.

Titrations

C04.T02 (T)

RP Chem 02: accurate endpoint

Do a rough run, then add acid dropwise near the colour change. Read the burette meniscus at eye level. Titre = final reading – initial reading. Repeat for closely agreeing titres and average these.

C04.T03 (T)

RP Chem 02: rinsing apparatus

Rinse the burette with its solution and pipette with the solution it measures; rinse the flask with distilled water. Extra distilled water in the flask does not change the moles of alkali.

C04.T04 (T)

RP Chem 02 concentration

For 25.0 cm³ NaOH neutralised by 20.0 cm³ of 0.100 mol/dm³ HCl: acid moles = 0.00200. The 1:1 ratio gives NaOH concentration 0.00200/0.0250 = 0.0800 mol/dm³.

Electrolysis

C04.26

(F) (H) (T)

Electrolyte

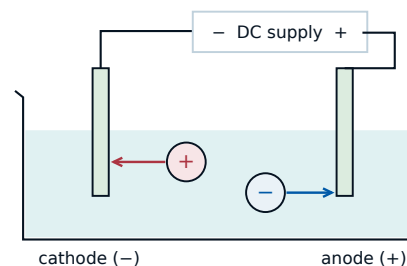
A molten or dissolved ionic substance whose mobile ions carry current.

C04.27

Electrolysis

(F) (H) (T)

Electrical decomposition of an electrolyte. Mobile ions move to electrodes and are discharged. PANIC: P = Positive; A = Anode; N = Negative; I = Is; C = Cathode. Remember: Positive Anode, Negative Is Cathode. This polarity reminder applies to electrolysis.



Charge carriers

Ions move through the electrolyte. Electrons flow through the metal wires and electrodes.

C04.28

(F) (H) (T)

Cathode

Negative electrode; positive ions move towards it.

C04.29

(F) (H) (T)

Anode

Positive electrode; negative ions move towards it.

C04.30

(F) (H) (T)

Molten binary compound

With inert electrodes, metal forms at the cathode and non-metal at the anode.

C04.31

(F) (H) (T)

Aqueous cathode rule

Metal forms if it is less reactive than hydrogen; otherwise hydrogen forms, using the GCSE inert-electrode model.

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Electrolysis

C04.32 **Aqueous anode rule** (F) (H) (T)

A halogen forms if halide ions are present; otherwise oxygen forms, using the GCSE inert-electrode model.

C04.33 **Aluminium extraction** (F) (H) (T)

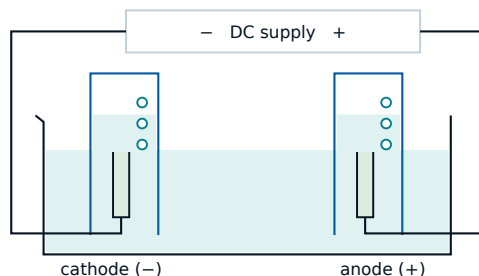
Electrolyse molten aluminium oxide mixed with cryolite. Cryolite lowers the operating temperature and energy cost.

C04.34 **Carbon anode replacement** (F) (H) (T)

Oxygen produced reacts with hot carbon anodes to form CO_2 , so the anodes wear away.

C04.35 **RP Com 09 / Chem 03: aqueous electrolysis** (F) (H) (T)

Use a low-voltage DC supply and inert electrodes; predict products, observe changes and test gases. Compare one electrolyte at a time.



Collect and test gases

Inverted, solution-filled tubes collect gas above each inert electrode. Wires enter from below the tube openings. Use a low-voltage DC supply.

C04.36 **RP Com 09 / Chem 03: controls and safety** (F) (H) (T)

Keep electrode area/spacing and supply conditions comparable. Use eye protection and ventilation; chlorine must not be inhaled. Gas-test facts are in C08.

C04.37 **Cathode half equations** (H) (T)

Reduction: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$; $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$. Balance both atoms and charge.

C04.38 **Anode half equations** (H) (T)

Oxidation: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$; $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$.

C04.R09 **Balancing half equations** (H) (T)

Balance each element first, then add electrons to balance charge. For $\text{Al}^{3+} \rightarrow \text{Al}$, add 3e^- to the left. For $2\text{Cl}^- \rightarrow \text{Cl}_2$, add 2e^- to the right. Reduction uses electrons; oxidation releases them. Never change a correct ion charge to force a balance.

C05 | Energy changes

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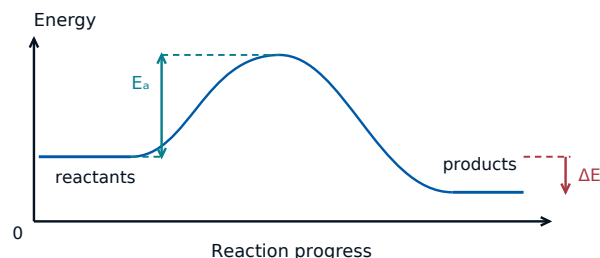
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Reaction energy

C05.01	(F)(H)(T)	Transfers energy to surroundings; their temperature rises. Products have lower energy than reactants.
C05.02	(F)(H)(T)	Combustion, many oxidation reactions and neutralisation; useful in hand warmers and self-heating containers.
C05.03	(F)(H)(T)	Takes in energy from surroundings; their temperature falls. Products have higher energy than reactants.
C05.04	(F)(H)(T)	Thermal decomposition and citric acid reacting with sodium hydrogencarbonate; some cold packs use such reactions.
C05.05	(F)(H)(T)	Minimum energy needed for reacting particles to undergo a successful reaction.

C05.06 Exothermic profile (F)(H)(T)

Products below reactants; the rise from reactants to the peak is activation energy. The overall change is downward.



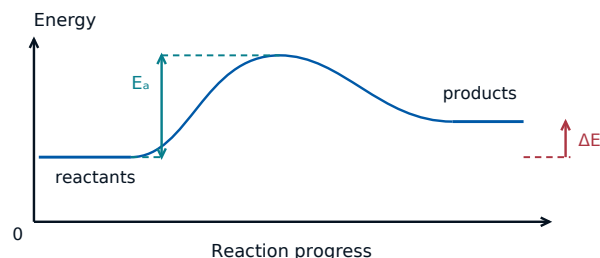
Exothermic

Products are lower in energy. Energy is transferred to the surroundings.

The activation energy is measured from the reactants to the peak.

C05.07 Endothermic profile (F)(H)(T)

Products above reactants; the overall change is upward. There is still an activation-energy barrier.



Endothermic

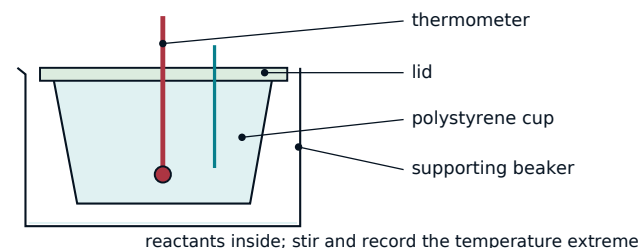
Products are higher in energy. Energy is transferred from the surroundings.

The activation energy is measured from the reactants to the peak.

Reaction energy

C05.08 RP Com 10 / Chem 04: temperature changes (F)(H)(T)

Measure initial temperature, mix measured reactants in an insulated cup and record the maximum/minimum temperature.



C05.09 RP Com 10 / Chem 04: temperature difference (F)(H)(T)

ΔT = final extreme temperature – initial temperature; positive for warming, negative for cooling.

C05.10 RP Com 10 / Chem 04: fair comparison (F)(H)(T)

Change one factor; control concentrations/volumes and starting temperature where appropriate. Use a lid, stir and repeat to reduce uncertainty.

Bond energies

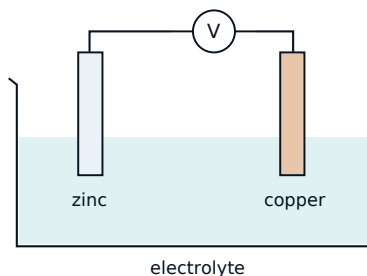
C05.11	(H)(T)	Requires energy: an endothermic process.
C05.12	(H)(T)	Releases energy: an exothermic process.
C05.13	(H)(T)	Overall energy change = sum of bond energies for bonds broken in the reactants – sum of bond energies for bonds formed in the products. Count every bond in the balanced equation.
C05.14	(H)(T)	Negative for exothermic (more released than absorbed); positive for endothermic (more absorbed than released).

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Cells and fuel cells

C05.T01 Simple chemical cell T

Two different metal electrodes in an electrolyte can produce a potential difference as a chemical reaction transfers energy electrically. Electrode and electrolyte choices affect the voltage.



Two different metals

The reacting chemicals supply energy. A voltmeter measures potential difference; the chosen metals and electrolyte affect the value.

C05.T02

Batteries T

Two or more cells connected in series provide a larger potential difference. A non-rechargeable cell stops when a reactant is exhausted.

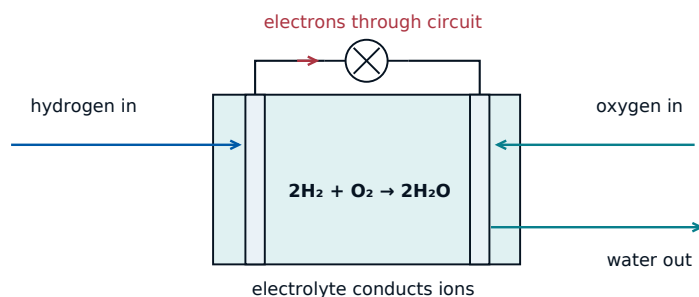
C05.T03

Rechargeable cells T

An external current reverses the chemical reactions. Compare stored energy, voltage, lifetime, mass, cost and environmental effects when choosing a cell.

C05.T04 Hydrogen fuel cell T

Hydrogen and oxygen are continuously supplied. The overall reaction is $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, transferring energy electrically.



C05.T05

Acidic fuel-cell half equations T

Hydrogen electrode: $2\text{H}_2 \rightarrow 4\text{H}^+ + 4\text{e}^-$. Oxygen electrode: $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$. Electrons travel through the external circuit.

Cells and fuel cells

C05.T06

Alkaline fuel-cell half equations T

Hydrogen electrode: $2\text{H}_2 + 4\text{OH}^- \rightarrow 4\text{H}_2\text{O} + 4\text{e}^-$. Oxygen electrode: $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$. Both give the same overall water-forming reaction.

C05.T07

Fuel cells versus batteries T

Fuel cells run while fuel is supplied and produce water at use. Hydrogen production may use fossil fuels or electricity; storage, transport and cost matter. Rechargeable batteries need charging and have finite capacity.

C06 | Rate and extent of chemical change

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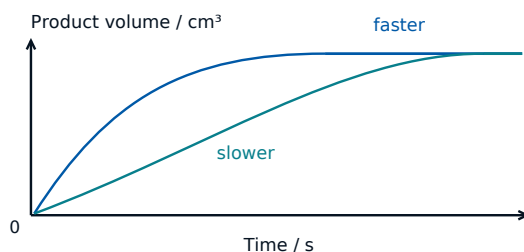
Rates and collisions

C06.01 **Mean reaction rate** (F H T) Quantity of reactant used or product formed ÷ time taken; common units g/s or cm³/s.

C06.02 **Rate in moles** (H T) Amount changed (mol) ÷ time (s), giving mol/s.

C06.03 **Rate graph** (F H T)

A steeper product-time curve means faster reaction; a plateau means no more product forms under those conditions.



Compare gradient and plateau

Steeper means faster. The same plateau means the same final amount of product in this example; it does not mean the rates were always equal.

C06.04 **Tangent to a curve** (F H T) A straight line matching the curve's direction at a chosen point; its slope represents the rate then.

C06.05 **Instantaneous rate** (H T) Gradient of a tangent = change in product quantity ÷ change in time, using two well-separated points on the tangent.

C06.06 **Collision theory** (F H T) Successful collisions occur when particles collide with enough energy to react (at least the activation energy). A higher frequency of successful collisions gives a faster reaction.

C06.07 **Concentration and pressure** (F H T) Higher concentration, or higher gas pressure at fixed temperature, puts more reactant particles in a given volume. This increases the frequency of successful collisions, so the rate increases.

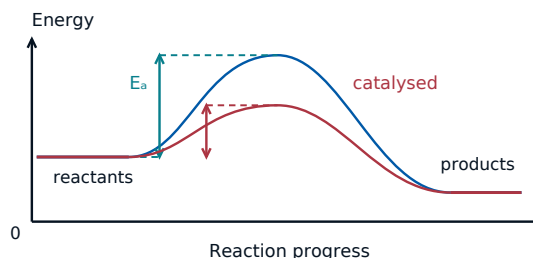
C06.08 **Surface area** (F H T) Smaller pieces of the same mass of solid give a greater exposed surface area. This increases the frequency of successful collisions at the surface, so the rate increases.

C06.09 **Temperature** (F H T) Higher temperature makes particles move faster. Collisions occur more often and a greater proportion have enough energy to react. The frequency of successful collisions increases.

Rates and collisions

C06.10 **Catalyst** (F H T)

Speeds a reaction by an alternative pathway with lower activation energy; not used up. Different reactions need different catalysts.

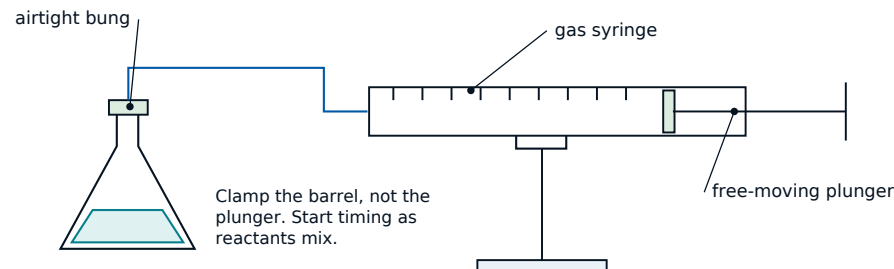


Lower barrier

Both pathways have the same reactant and product energies. The catalyst lowers activation energy without changing the overall energy change.

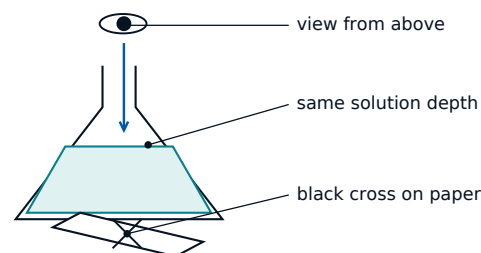
C06.11 **RP Com 11 / Chem 05: gas method** (F H T)

Change reactant concentration; collect gas in a syringe and record volume at regular times. Prevent leaks and keep other quantities/temperature constant.



C06.12 **RP Com 11 / Chem 05: turbidity method** (F H T)

Time how long a cross takes to disappear as a precipitate forms. Use the same endpoint, depth and viewing conditions; relative rate = 1/time.



Consistent endpoint

Stop timing when the cross can no longer be seen through the precipitate.

C06 | Rate and extent of chemical change

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Rates and collisions

C06.13 (F) (H) (T)

RP Com 11 / Chem 05: evaluation and safety

Repeat each concentration; subjective endpoints and gas leaks create uncertainty. Use eye protection and appropriate ventilation for any irritating gases.

Reversible reactions

C06.14 (F) (H) (T)

Reversible reaction

Products can react to reform reactants; shown by $\rightleftharpoons$. Changing conditions can favour either direction.

C06.15 (F) (H) (T)

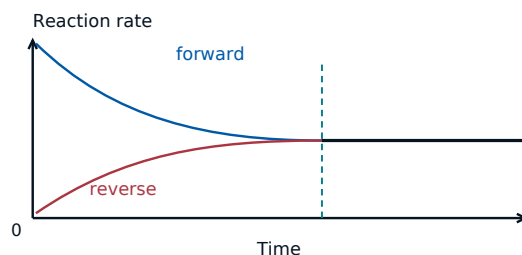
Reverse energy change

If forward is exothermic, reverse is endothermic by the same amount, and vice versa.

C06.16 **Dynamic equilibrium**

(F) (H) (T)

In a closed system, forward and reverse reactions continue at equal rates; concentrations remain constant, not necessarily equal.



Equal rates

After equilibrium is reached, both reactions continue. Reactant and product concentrations stay constant; they need not be equal.

Changing equilibrium

C06.17 (H) (T)

Le Chatelier's principle

After a change in conditions, an equilibrium shifts in the direction that counteracts the change.

C06.18 (H) (T)

Concentration change

Adding a reactant favours its consumption; removing a product favours formation of more product.

C06.19 (H) (T)

Temperature change

Higher temperature favours the endothermic direction; lower temperature favours the exothermic direction.

C06.20 (H) (T)

Pressure change

Higher gas pressure favours the side with fewer gas molecules; lower pressure favours more. Equal gas-molecule counts give no shift.

C06.21 (H) (T)

Catalyst at equilibrium

Reaches equilibrium sooner by increasing both reaction rates; it does not change the equilibrium position.

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Hydrocarbons		
C07.01 Crude oil	(F)(H)(T)	A finite mixture of hydrocarbons formed over millions of years from ancient biomass, mainly buried plankton.
C07.02 Hydrocarbon	(F)(H)(T)	A compound containing only hydrogen and carbon.
C07.03 Alkane	(F)(H)(T)	A saturated hydrocarbon with only single carbon-carbon bonds; general formula C_nH_{2n+2} .
C07.04 First four alkanes (F)(H)(T)		
Methane CH_4 ; ethane C_2H_6 ; propane C_3H_8 ; butane C_4H_{10} .		
methane <pre> H H - C - H H </pre> CH_4 ethane <pre> H H H - C - C - H H H </pre> C_2H_6 propane <pre> H H H H - C - C - C - H H H H </pre> C_3H_8 butane <pre> H H H H H - C - C - C - C - H H H H H </pre> C_4H_{10} Every carbon has four bonds; every hydrogen has one.		
C07.05 Homologous series	(F)(H)(T)	A family of compounds with a common general formula and similar chemical properties.
C07.06 Crude-oil fractions	(F)(H)(T)	Mixtures of hydrocarbons with similar boiling points and similar numbers of carbon atoms.
C07.07 Fractionating column (F)(H)(T)		
Hot at the bottom, cooler at the top; vapours condense at different heights according to boiling point.		
Vapours rise, cool and condense where the temperature falls below their boiling range. heated crude-oil vapour cooler at top short chains; lowest boiling points intermediate fractions long chains; highest boiling points hotter at bottom		

Hydrocarbons		
C07.08 Hydrocarbon size trends	(F)(H)(T)	Longer molecules: higher boiling point, greater viscosity and lower flammability.
C07.09 Fuels and feedstock	(F)(H)(T)	Fractions supply petrol, diesel, kerosene and other fuels; petrochemical feedstocks make polymers, solvents, lubricants and detergents.
C07.10 Complete combustion	(F)(H)(T)	Hydrocarbon + oxygen → carbon dioxide + water; energy is transferred to surroundings. Balance carbon, hydrogen, then oxygen atoms.
C07.11 Cracking (F)(H)(T)		
Breaks larger hydrocarbons into smaller, more useful molecules, including alkanes and alkenes.		
$C_{10}H_{22} \xrightarrow{\text{heat / catalyst}} C_8H_{18} + C_2H_4$ long alkane shorter alkane alkene 10 carbon atoms and 22 hydrogen atoms on both sides one valid illustrative split; cracking makes a mixture of products		
C07.12 Catalytic cracking	(F)(H)(T)	Vaporise hydrocarbons and pass vapour over a hot catalyst.
C07.13 Steam cracking	(F)(H)(T)	Mix hydrocarbon vapour with steam and heat to a very high temperature.
C07.14 Alkene	(F)(H)(T)	An unsaturated hydrocarbon containing a carbon-carbon double bond; more reactive than an alkane.
C07.15 Bromine-water test	(F)(H)(T)	An alkene decolourises orange bromine water; an alkane does not under these test conditions.
C07.16 Why crack hydrocarbons?	(F)(H)(T)	Demand is high for small fuel molecules and for alkenes used to make polymers and other chemicals.

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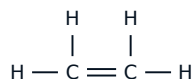
Alkenes and addition reactions

C07.T01 Alkene series

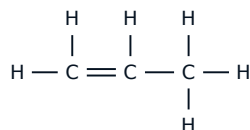
(T)

Ethene C_2H_4 , propene C_3H_6 , butene C_4H_8 and pentene C_5H_{10} follow C_nH_{2n} for one double bond in an open chain. $C=C$ is the functional group.

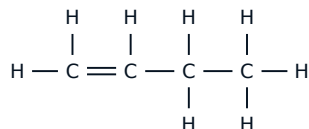
Ethene



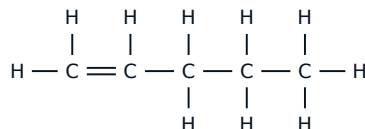
Propene



Butene



Pentene

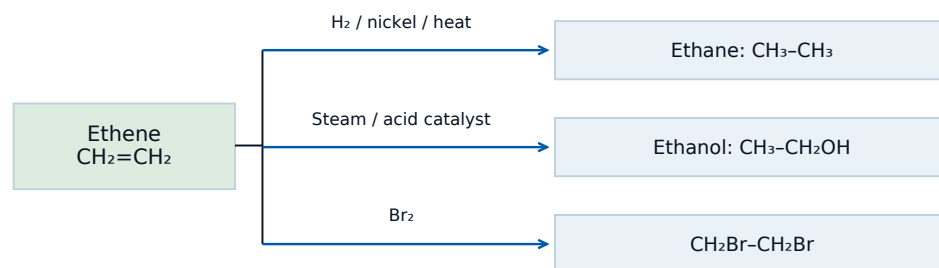


Displayed structures of the named GCSE examples.

C07.T02 Addition reactions

(T)

Atoms add across $C=C$, making a $C-C$ bond. Hydrogen forms an alkane with a nickel catalyst and heat; steam forms an alcohol with an acid catalyst at high temperature and pressure.



C07.T03 Adding halogens

(T)

Chlorine, bromine or iodine adds one atom to each carbon of the former double bond. Bromine water decolourises without needing UV light; no hydrogen atom is displaced.

C07.T04 Alkene combustion

(T)

Complete combustion gives CO_2 and water. In air, alkenes often burn with a smokier flame because incomplete combustion forms soot.

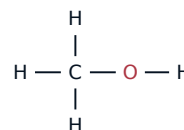
Alcohols and carboxylic acids

C07.T05 First four alcohols

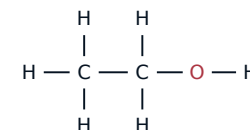
(T)

Methanol CH_3OH ; ethanol C_2H_5OH ; propanol C_3H_7OH ; butanol C_4H_9OH . The alcohol functional group is $-OH$. Recognise their displayed structures.

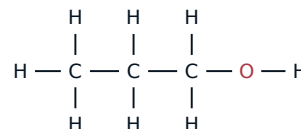
Methanol



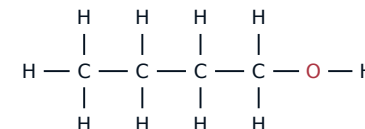
Ethanol



Propanol



Butanol



Displayed structures of the named GCSE examples.

C07.T06 Alcohol reactions and uses

(T)

Small alcohols dissolve in water to make neutral solutions. They burn as fuels; they are also solvents. Sodium produces hydrogen and an alkoxide; oxidation can form a carboxylic acid.

C07.T07 Ethanol combustion

(T)

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$. Balance carbon and hydrogen first, then oxygen; incomplete combustion can occur with limited oxygen.

C07.T08 Fermentation conditions

(T)

Yeast converts sugar to ethanol and CO_2 without oxygen, in a warm aqueous solution, typically around $30-40^\circ C$. Too cold slows enzymes; excessive heat kills yeast. Distillation can concentrate ethanol.

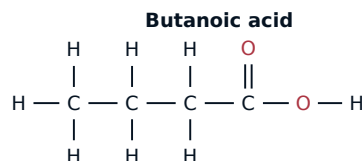
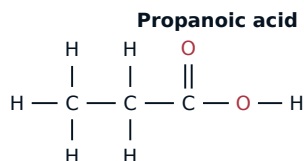
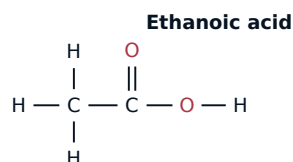
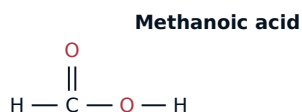
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Alcohols and carboxylic acids

C07.T09 First four carboxylic acids Ⓣ

Methanoic HCOOH, ethanoic CH₃COOH, propanoic C₂H₅COOH and butanoic C₃H₇COOH. Each has the -COOH functional group.



Displayed examples; longer chains can have other arrangements not shown.

C07.T10 Ⓣ Carboxylic-acid reactions

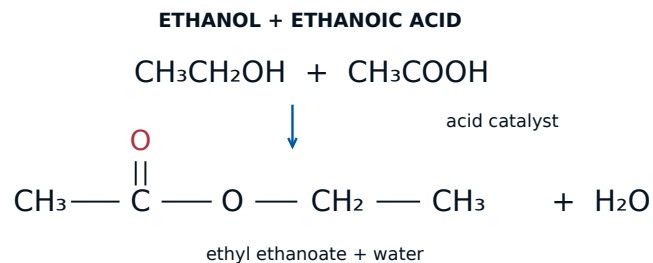
Dissolve in water to form acidic solutions. With carbonates they form a salt, water and CO₂. With an alcohol and acid catalyst they can form an ester and water.

C07.T11 Ⓣ Weak carboxylic acids

Only some molecules ionise in water. At the same concentration a weak acid has fewer H⁺ ions and a higher pH than a strong acid.

C07.T12 Ethyl ethanoate Ⓣ

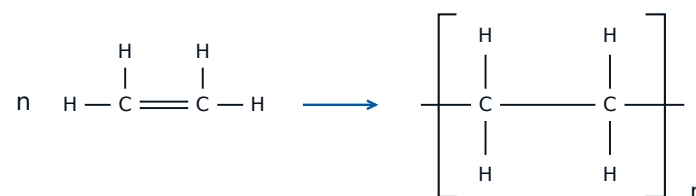
Ethanol + ethanoic acid ⇌ ethyl ethanoate + water, with an acid catalyst. Esters often have distinctive fruity smells.



Polymers

C07.T13 Addition polymerisation Ⓣ

Many alkene monomers join as C=C bonds open. The repeating unit contains every atom from the monomer; no small-molecule by-product is formed.



Poly(ethene)

C=C becomes C-C. Each carbon keeps its two H atoms. Continuation bonds cross the brackets.

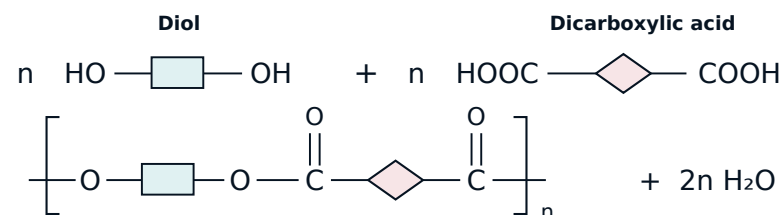
One ethene monomer supplies one repeating unit; no atoms are discarded.

C07.T14 Ⓣ Drawing a repeating unit

Change C=C to C-C, keep each carbon's attached groups, draw continuation bonds through brackets and put n outside. Reverse this process to identify an alkene monomer.

C07.T15 Condensation polymerisation Ⓣ

Monomers with two reactive functional groups join, releasing small molecules such as water. A diol and a dicarboxylic acid form a polyester. The shapes stand for the rest of each molecule.



Polyester repeating unit: ester links join the shaped sections. Shapes represent carbon chains; chain ends are not shown.

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Polymers

C07.T16 Amino acids and proteins



An amino acid has -NH_2 and -COOH groups. Condensation forms peptide links and water; amino-acid sequences form polypeptides and proteins. Glycine is $\text{H}_2\text{NCH}_2\text{COOH}$.

AMINO ACID



Condensation forms peptide links (-CONH-) and releases water.

C07.T17 Natural polymers



Starch and cellulose are made from glucose; proteins from amino acids; DNA from nucleotides. Most DNA contains two nucleotide chains in a double helix and stores genetic information.

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Purity and separation	
C08.01 Pure substance	One element or compound with no other substance mixed in; different from everyday uses of the word pure.
C08.02 Purity and temperature	Pure substances have specific melting/boiling points at a given pressure; impurities often broaden the melting range and change it.
C08.03 Formulation	A deliberately designed mixture with measured ingredient proportions to achieve useful properties, such as a paint, fuel or medicine.
C08.04 Chromatography phases	The mobile phase moves through a stationary phase. Different distributions between the phases cause separation.
C08.05 Paper chromatography	Soluble substances move with solvent but spend different amounts of time held by the paper, so travel different distances.
C08.06 Rf value	
Distance from baseline to centre of substance spot ÷ distance from baseline to solvent front; no unit. Measure from one baseline $R_f = \text{distance to the spot centre} \div \text{distance to the solvent front}$. Both distances start at the pencil baseline.	
C08.07 Interpreting spots	Several spots show a mixture. Matching R_f values under the same conditions support identification; one spot alone is not absolute proof of purity.

Purity and separation	
C08.08 RP Com 12 / Chem 06: setting up	
Draw a pencil baseline; apply small spots; stand paper in solvent below the baseline. Keep the vessel covered. Spots must not be submerged in the solvent reservoir.	
C08.09 RP Com 12 / Chem 06: finishing	Remove before the solvent reaches the top; mark the solvent front immediately and measure both distances from the same baseline.
C08.10 RP Com 12 / Chem 06: reasons	Pencil does not dissolve like ink; keeping spots above solvent prevents them dissolving straight into the reservoir. Use the same solvent/conditions for comparisons.
Gas tests	
C08.11 Hydrogen test	A lighted splint at the mouth of the tube gives a squeaky pop.
C08.12 Oxygen test	A glowing splint inserted into the gas relights.
C08.13 Carbon dioxide test	Bubble through limewater: it turns cloudy/milky.
C08.14 Chlorine test	Damp litmus paper is bleached white; do not identify it by inhaling it.

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Identifying ions

C08.T01 RP Chem 07: flame tests

(T)

Lithium: crimson; sodium: yellow; potassium: lilac; calcium: orange-red; copper: green. Use a clean loop and a non-luminous flame. Mixtures can mask a colour.



Lithium
crimson



Sodium
yellow



Potassium
lilac



Calcium
orange-red



Copper
green

C08.T02 (T) RP Chem 07: white hydroxides

Add sodium hydroxide solution: Al^{3+} , Ca^{2+} and Mg^{2+} give white precipitates. Only the aluminium precipitate dissolves in excess sodium hydroxide.

C08.T03 RP Chem 07: coloured hydroxides

(T)

With sodium hydroxide, Cu^{2+} forms a blue precipitate, Fe^{2+} green and Fe^{3+} brown.

Add sodium hydroxide solution

Cu^{2+}



blue precipitate

Fe^{2+}



green precipitate

Fe^{3+}



brown precipitate

C08.T04 (T) Hydroxide equations

$\text{Cu}^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2$. For Fe^{3+} use three OH^- to form $\text{Fe}(\text{OH})_3$. Balance atoms and charge; include spectator ions if writing a full equation.

C08.T05 (T) RP Chem 07: carbonates

Add dilute acid: bubbling suggests a gas. Pass it through limewater; cloudiness identifies CO_2 and supports the presence of carbonate ions.

Identifying ions

C08.T06 RP Chem 07: halides

(T)

Acidify a fresh sample with dilute nitric acid, then add silver nitrate. Chloride: white precipitate; bromide: cream; iodide: yellow.

Dilute nitric acid, then silver nitrate solution

Cl^-



white precipitate

Br^-



cream precipitate

I^-



yellow precipitate

C08.T07 (T) RP Chem 07: sulfates

Acidify a fresh sample with dilute hydrochloric acid, then add barium chloride solution. A white barium sulfate precipitate indicates sulfate ions.

C08.T08 (T) RP Chem 07: reliable identification

Use separate clean portions for each test and compare with controls or known results. Record reagent, observation and inference separately; use eye protection and the approved disposal method.

Instrumental analysis

C08.T09 (T) Instrumental methods

Can be faster, more sensitive and more accurate than simple chemical tests; equipment cost and calibration still matter.

C08.T10 Flame emission spectroscopy

(T)

Excited metal ions emit characteristic wavelengths. A spectroscope separates the light into lines: positions identify ions and calibrated intensity indicates concentration.

Reference A



Reference B



Unknown



Illustrative spectra; horizontal position represents wavelength.

Match positions

The unknown contains lines from both references, so it is consistent with a mixture of A and B. Intensity can be calibrated for concentration.

C08.T11 (T) Reading an emission spectrum

Compare all line positions with reference spectra. A mixture may contain lines from more than one element; a calibration graph links intensity to concentration.

C09 | Chemistry of the atmosphere

Knowledge Organiser | Item Icons Give Course Scope | Unit Page 1 of 1

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Atmospheric change		
C09.01 Modern atmosphere	(F)(H)(T)	About 78% nitrogen, 21% oxygen and 1% other gases; CO ₂ is about 0.04%, with variable water vapour. These are approximate revision values.
C09.02 Early-atmosphere model	(F)(H)(T)	Volcanic activity released mainly CO ₂ , water vapour and nitrogen, with little/no oxygen; smaller amounts of methane and ammonia may have occurred.
C09.03 Early evidence limits	(F)(H)(T)	Earth formed about 4.6 billion years ago; few records survive, so reconstructions use indirect evidence.
C09.04 Ocean formation	(F)(H)(T)	As Earth cooled, water vapour condensed. CO ₂ dissolved in oceans and became locked into carbonate sediments.
C09.05 Oxygen increase	(F)(H)(T)	Photosynthetic algae and later plants removed CO ₂ and released oxygen; algae began doing so about 2.7 billion years ago.
C09.06 Carbon stores	(F)(H)(T)	Limestone contains carbonate from sediments/shells; coal formed from buried plants; oil/gas from ancient buried biomass. These processes removed atmospheric carbon.
Greenhouse gases and climate		
C09.07 Greenhouse gases	(F)(H)(T)	Water vapour, CO ₂ and methane absorb outgoing long-wavelength infrared radiation.
C09.08 Greenhouse effect	(F)(H)(T)	Much incoming short-wavelength radiation reaches the surface; the warmed Earth emits infrared, which greenhouse gases absorb and re-emit.
C09.09 Human CO₂ sources	(F)(H)(T)	Burning fossil fuels and deforestation increase atmospheric CO ₂ .
C09.10 Human methane sources	(F)(H)(T)	Livestock farming, rice paddies and decomposing landfill waste release methane.

Greenhouse gases and climate		
C09.11 Climate consequences	(F)(H)(T)	Sea-level rise, changes in rainfall/water supply, more extreme weather and shifts in habitats/species distributions.
C09.12 Climate evidence	(F)(H)(T)	Use long-term observations, models and peer-reviewed research; distinguish uncertainty in precise predictions from the evidence for warming.
C09.13 Carbon footprint	(F)(H)(T)	Total greenhouse-gas emissions across a product, service or event's whole life cycle, commonly expressed as CO ₂ equivalent.
C09.14 Reducing the footprint	(F)(H)(T)	Use less energy, lower-emission energy/transport, reduce waste and methane leaks, and protect forests. Cost, infrastructure and cooperation can limit action.
Air pollution		
C09.15 Carbon monoxide	(F)(H)(T)	Produced by incomplete combustion; toxic, colourless and odourless. It reduces blood's ability to carry oxygen.
C09.16 Soot and particulates	(F)(H)(T)	Incomplete combustion produces carbon particles; they damage health and can reduce sunlight reaching Earth (global dimming).
C09.17 Sulfur dioxide	(F)(H)(T)	Burning sulfur impurities in fuels produces SO ₂ ; it irritates lungs and contributes to acid rain.
C09.18 Nitrogen oxides	(F)(H)(T)	At high engine temperatures, nitrogen and oxygen react; nitrogen oxides cause respiratory problems and contribute to acid rain.

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Resources and drinking water

C10.01 Finite / renewable	(F)(H)(T)	Finite resources are used faster than they form; renewable resources can be replenished on human timescales if managed sustainably.
C10.02 Sustainable development	(F)(H)(T)	Meeting present needs while preserving future generations' ability to meet theirs.
C10.03 Natural and synthetic products	(F)(H)(T)	Agriculture supplies timber/cotton and biofuels; synthetic materials such as plastics can supplement or replace natural products.
C10.04 Potable water	(F)(H)(T)	Safe to drink, with sufficiently low microbes and dissolved salts; it is not chemically pure water.

C10.05 UK freshwater treatment (F)(H)(T)

Choose a suitable source → filter out solids → sterilise using chlorine, ozone or ultraviolet light.

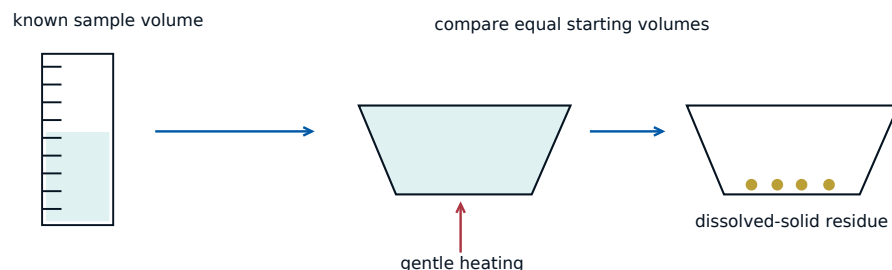


Filtration removes solids; sterilisation kills microbes. Potable does not mean chemically pure.

C10.06 Desalination	(F)(H)(T)	Removes dissolved salts from seawater by distillation or reverse osmosis; energy demand is a major disadvantage.
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C10.07 RP Com 13 / Chem 08: testing water (F)(H)(T)

Measure pH; evaporate a known sample volume to compare dissolved-solid residues; do not drink laboratory samples.



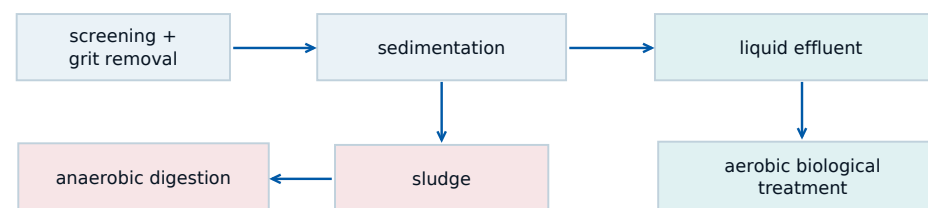
Resources and drinking water

C10.08 RP Com 13 / Chem 08: purification	(F)(H)(T)	Distil a sample: heat to make vapour, cool vapour in a condenser and collect distillate. Dissolved salts remain in the flask.
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Waste water and metal recovery

C10.09 Sewage-treatment sequence (F)(H)(T)

Screen/grit removal → sedimentation → anaerobic digestion of sludge and aerobic biological treatment of liquid effluent.



Separate liquid and solid treatment routes

C10.10 Industrial waste water	(F)(H)(T)	May require removal of toxic chemicals as well as organic matter before safe release.
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C10.11 Phytomining	(H)(T)	Plants absorb metal compounds; harvest and burn them, then recover metal compounds from the ash.
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C10.12 Bioleaching	(H)(T)	Bacteria help produce a leachate containing dissolved metal compounds from low-grade ores.
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C10.13 Copper recovery	(H)(T)	Copper can be recovered from solution by displacement with scrap iron or by electrolysis. Biological extraction reduces rock removal but can be slow.
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Life cycles and recycling

C10.14 Life cycle assessment (F) (H) (T)

Evaluates raw materials, manufacture/packaging, use and disposal, including transport at every stage.



Include transport, energy, water and waste at every relevant stage.

C10.15 (F) (H) (T) LCA limits

Energy/water use can be measured; weighting pollution damage involves judgement. Selective boundaries can bias comparisons.

C10.16 (F) (H) (T) Reduce / reuse / recycle

Use less material; use a product again; or reprocess material into new products. These reduce extraction and waste.

C10.17 (F) (H) (T) Metal and glass recycling

Sort as needed, melt and reform; generally reduces demand for ores/raw materials and energy compared with new extraction.

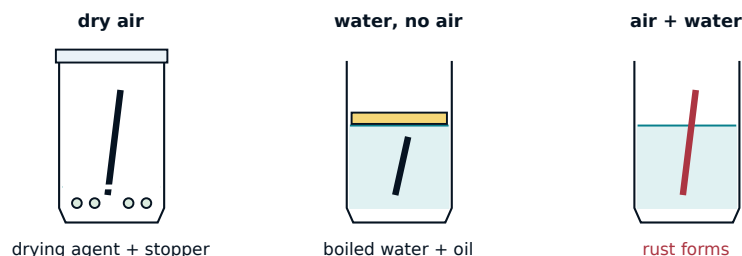
C10.18 (F) (H) (T) Recycling trade-offs

Collection, transport, sorting and processing also use energy; compare the full life cycle and required material quality.

Corrosion and alloys

C10.T01 Rusting (T)

Iron corrodes when both oxygen and water are present. Compare nails in dry air, air-free water and air plus water to test the conditions.



Corrosion and alloys

C10.T02 (T) Barrier protection

Paint, grease or electroplating prevents contact with air and water while intact. Aluminium's adherent oxide layer protects the underlying metal.

C10.T03 (T) Sacrificial protection

Attach a more reactive metal, such as zinc or magnesium, which oxidises instead of iron. Galvanising coats iron in zinc and can protect it even if scratched.

C10.T04 (T) Copper alloys

Bronze = copper + tin, used for statues and bearings. Brass = copper + zinc, used for fittings and musical instruments.

C10.T05 (T) Gold alloys

Pure gold is 24 carat and relatively soft. Alloying with metals such as silver, copper and zinc makes jewellery harder. Gold percentage = $\text{carat} \div 24 \times 100$; 18 carat is 75%.

C10.T06 (T) Steel types

High-carbon steel is strong but brittle, useful for cutting tools. Low-carbon steel is softer and easily shaped for car bodies. Chromium/nickel stainless steel resists corrosion, useful for cutlery.

C10.T07 (T) Aluminium alloys

Low density combined with improved strength makes them useful for aircraft and other lightweight structures. Alloy structure has its home in C02.

Ceramics, polymers and composites

C10.T08 (T) Glass and clay ceramics

Soda-lime glass uses sand, sodium carbonate and limestone. Borosilicate glass uses sand and boron trioxide and withstands higher temperatures. Shaped wet clay is fired to make bricks and pottery.

C10.T09 (T) Poly(ethene) conditions

High pressure with a little oxygen produces low-density poly(ethene). A catalyst at lower pressure and temperature produces high-density poly(ethene); straighter chains pack more closely.

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Ceramics, polymers and composites

C10.T10 Thermosoftening versus thermosetting

T

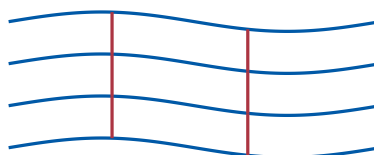
Thermosoftening polymers have chains that can slide when heated. Thermosetting polymers have covalent cross-links between chains, preventing melting.

THERMOFTENING



chains can slide on heating

THERMOSETTING

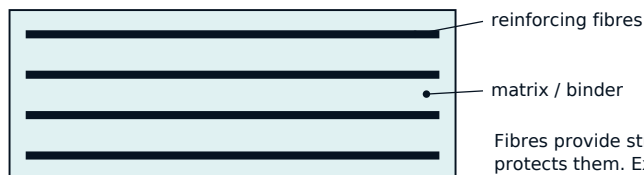


covalent cross-links prevent flow

C10.T11 Composites

T

A matrix binds reinforcement, combining useful properties. Examples: glass fibres in resin (fibreglass), carbon fibres in polymer, and steel bars in concrete.



Fibres provide strength; the matrix holds and protects them. Example: glass fibres in polymer resin.

C10.T12 Choosing a material

T

Compare stiffness, strength, density, thermal properties, durability and cost with the use. Use numerical evidence when supplied; a material's name alone does not establish suitability.

Haber process and fertilisers

C10.T13 Haber reactants

T

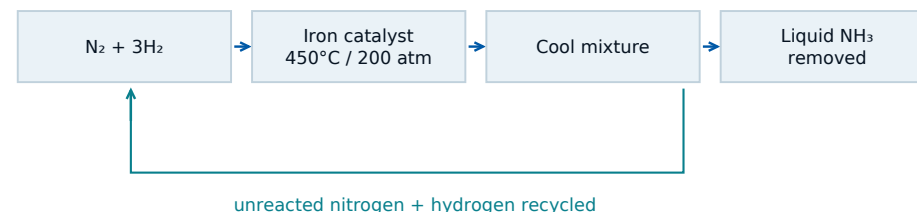
Nitrogen is obtained from air; hydrogen commonly comes from natural gas. $N_2 + 3H_2 \rightleftharpoons 2NH_3$; the forward reaction is exothermic.

Haber process and fertilisers

C10.T14 Haber plant

T

Purified gases pass over iron at about 450°C and 200 atmospheres. Cool the mixture to liquefy and remove ammonia; recycle unreacted gases.



Reversible reaction: $N_2 + 3H_2 \rightleftharpoons 2NH_3$. The forward reaction releases energy.

C10.T15 Haber compromises

T

Lower temperature favours ammonia but slows reaction. Higher pressure favours ammonia and raises rate but increases costs and hazards. Iron speeds approach to equilibrium without changing the equilibrium yield.

C10.T16 NPK fertilisers

T

Formulations provide nitrogen, phosphorus and potassium compounds in useful proportions to improve growth and yield. Ammonia supplies ammonium salts and can be used to make nitric acid.

C10.T17 Ammonium nitrate

T

Ammonia neutralises nitric acid: $NH_3 + HNO_3 \rightarrow NH_4NO_3$. Industrial production is continuous and controlled; laboratory preparation works in smaller batches with different separation arrangements.

C10.T18 Potassium and phosphate sources

T

Potassium chloride and sulfate are mined. Insoluble phosphate rock must be treated with acids to make phosphate available to plants.

C10.T19 Processing phosphate rock

T

Nitric acid gives phosphoric acid and calcium nitrate. Sulfuric acid gives single superphosphate (calcium dihydrogen phosphate plus calcium sulfate). Phosphoric acid gives triple superphosphate (calcium dihydrogen phosphate), without calcium sulfate.

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Stores and transfers		
P01.01 System	(F)(H)(T)	An object or group of objects considered together.
P01.02 Energy stores	(F)(H)(T)	Kinetic, thermal/internal, chemical, gravitational potential, elastic potential, magnetic, electrostatic and nuclear.
P01.03 Transfer pathways	(F)(H)(T)	Mechanically (a force does work), electrically (moving charge), by heating and by radiation.
P01.04 Energy unit	(F)(H)(T)	The joule, J. Energy is stored in systems and transferred between them.
P01.05 Kinetic energy	(F)(H)(T)	$E_k = \frac{1}{2}mv^2$. E_k in J; m in kg; speed v in m/s. Doubling speed quadruples kinetic energy.
P01.06 Gravitational potential energy	(F)(H)(T)	$E_p = mgh$. E_p in J; m in kg; g in N/kg; vertical height change h in m.
P01.07 Elastic potential energy	(F)(H)(T)	$E_e = \frac{1}{2}ke^2$, within the limit of proportionality. E_e in J; k in N/m; extension e in m.
P01.08 Thermal energy change	(F)(H)(T)	$\Delta E = mc\Delta\theta$. ΔE in J; m in kg; c in J/(kg °C); temperature change $\Delta\theta$ in °C.
P01.09 Specific heat capacity	(F)(H)(T)	Energy needed to raise 1 kg of a substance by 1 °C, with no change of state.
P01.10 Power	(F)(H)(T)	Rate of energy transfer or work done: $P = E/t = W/t$. P in W; E or work W in J; t in s. 1 W = 1 J/s.

Rearrangement reminder

$E = P \times t$. Divide the top quantity by one lower quantity to find the other. Use the stated units.

Use the equation and check units.

Stores and transfers		
P01.11 RP Com 14 / Phys 01: specific heat capacity	(F)(H)(T)	Measure block mass and initial temperature; use an electric heater for a measured time and record the temperature rise. Calculate c from energy/(mass $\times$ rise).

to low-voltage supply / joulemeter

measure mass, electrical energy supplied and temperature rise

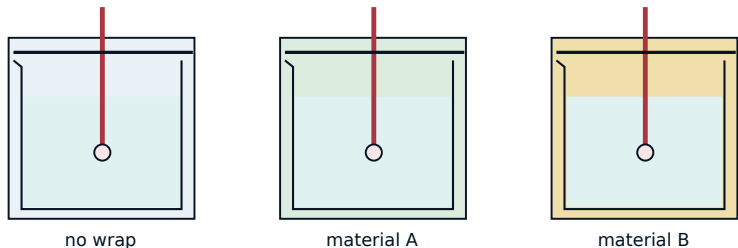
P01.12 RP Com 14 / Phys 01: improvements	(F)(H)(T)	Insulate the block, improve heater/thermometer contact, and allow readings to settle. Energy lost to surroundings makes calculated c too large if all input is assumed to heat the block.
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Conservation and efficiency		
P01.13 **Conservation of energy**	(F)(H)(T)	Energy cannot be created or destroyed. In a closed system, total energy remains constant.
P01.14 **Dissipation**	(F)(H)(T)	Energy spreads into less useful thermal stores of the surroundings; it has not disappeared.
P01.15 **Reducing unwanted transfers**	(F)(H)(T)	Lubrication reduces friction; insulation reduces heat transfer. Thicker, less thermally conducting walls slow cooling.
P01.16 **Efficiency**	(F)(H)(T)	Useful output energy $\div$ total input energy; or useful output power $\div$ total input power. Multiply by 100 for a percentage.

Widths represent energy

Input width = useful branch + dissipated branch. This illustrative example gives efficiency $60/100 = 60\%$.

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Conservation and efficiency	
P01.17 Increasing efficiency (H) (T)	Reduce transfers that do not contribute to the intended output, such as frictional heating or electrical heating in supply cables.
Thermal insulation practical	
P01.T01 RP Phys 02: thermal insulation (T)	Compare cooling of equal volumes of hot water in identical containers with different insulating materials, or different thicknesses of one material. Record temperature at equal time intervals.
Same hot water volume and starting temperature  no wrap material A material B Read temperature at equal time intervals.	
P01.T02 RP Phys 02: fair comparison (T)	Control starting temperature, water volume, container, lid, exposed area and room conditions. Repeat; a smaller temperature fall over the same time indicates better insulation under these conditions.
Energy resources	
P01.18 Non-renewable resources (F) (H) (T)	Coal, oil, natural gas and nuclear fuel; reserves are finite.
P01.19 Renewable resources (F) (H) (T)	Biofuel, wind, hydroelectric, geothermal, tidal, solar and wave resources.
P01.20 Fossil fuels (F) (H) (T)	Reliable, controllable supply for transport/heating/electricity; release CO ₂ and pollutants.
P01.21 Nuclear fuel (F) (H) (T)	Reliable electricity with low operational CO ₂ ; radioactive waste and decommissioning require management.
P01.22 Wind and solar (F) (H) (T)	No fuel combustion during operation; output depends on weather/daylight, so storage or backup may be needed.
P01.23 Hydroelectric and tidal (F) (H) (T)	Hydroelectric output can be controlled if water is available; tides are predictable. Both can affect habitats.

Energy resources	
P01.24 Geothermal and waves (F) (H) (T)	Geothermal is reliable in suitable locations; wave power is variable and challenging in harsh marine conditions.
P01.25 Biofuels (F) (H) (T)	Can supply heating, transport and electricity; regrowth can absorb CO ₂ , but land use, processing and transport affect total impact.
P01.26 Resource decisions (F) (H) (T)	Compare reliability, cost, emissions, land/habitat effects and local availability; scientific evidence informs but does not alone decide policy.

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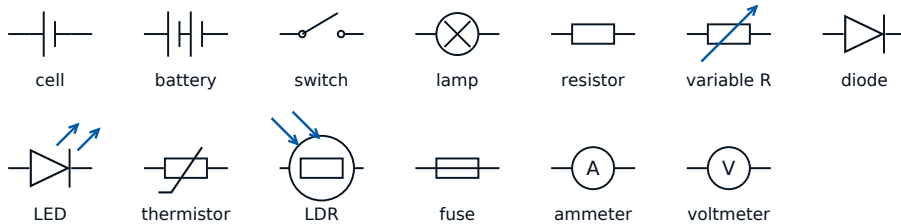
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Circuits and electrical quantities

P02.01 Circuit symbols

(F) (H) (T)

Use standard symbols for cell/battery, switch, lamp, resistor, variable resistor, diode, LED, thermistor, LDR, fuse, ammeter and voltmeter.



P02.02 Electric current

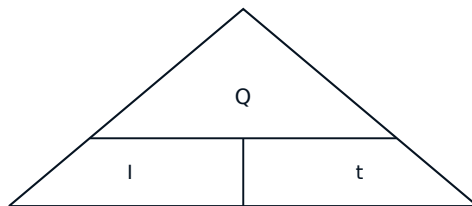
(F) (H) (T)

Rate of charge flow. A closed conducting path and a source of potential difference are needed for sustained current.

P02.03 Charge equation

(F) (H) (T)

$Q = It$. Charge Q in C; current I in A; time t in s.



Use the equation and check units.

Rearrangement reminder

$Q = I \times t$. Divide the top quantity by one lower quantity to find the other. Use the stated units.

P02.04 Potential difference

(F) (H) (T)

Energy transferred per unit charge between two points; measured in volts, V.

P02.05 Resistance

(F) (H) (T)

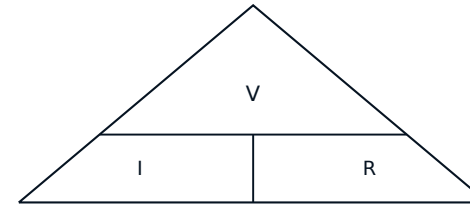
Opposition to current; $R = V/I$, measured in ohms, Ω . At fixed V , larger R means smaller I .

Circuits and electrical quantities

P02.06 Ohm's law equation

(F) (H) (T)

$V = IR$. V in volts; I in amperes; R in ohms.



Use the equation and check units.

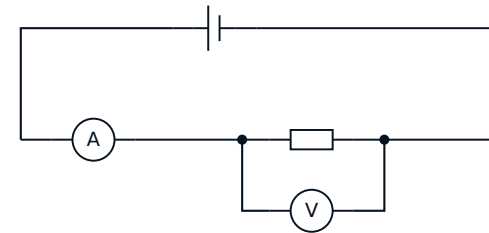
Rearrangement reminder

$V = I \times R$. Divide the top quantity by one lower quantity to find the other. Use the stated units.

P02.07 Ammeter and voltmeter

(F) (H) (T)

Ammeter in series measures current; voltmeter in parallel measures potential difference across a component.



Correct meter placement

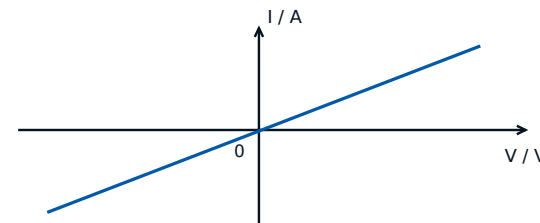
Ammeter: in series. Voltmeter: across the test component. Junction dots show electrical connections.

The voltmeter connects to the two ends of the component being measured.

P02.08 Ohmic conductor

(F) (H) (T)

At constant temperature, current is directly proportional to potential difference: a straight I-V line through the origin.



Read the characteristic

Straight through the origin when temperature is constant: current is proportional to potential difference.

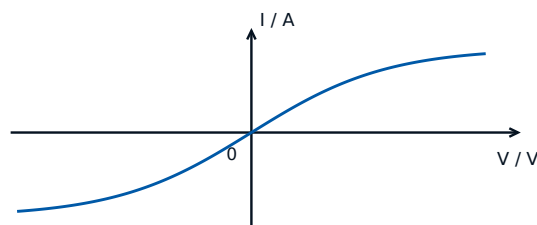
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Circuits and electrical quantities

P02.09 Filament lamp

(F) (H) (T)

As current heats the filament, resistance rises; the I-V curve becomes less steep at larger magnitudes of V.



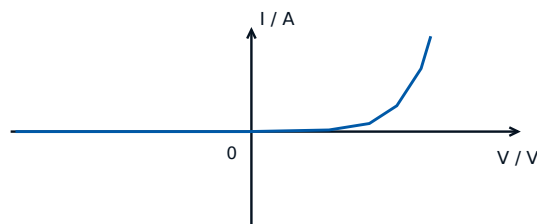
Read the characteristic

As the filament heats, resistance increases. The graph flattens at larger positive and negative potential differences.

P02.10 Diode

(F) (H) (T)

Conducts mainly in one direction; very high resistance in reverse direction.



Read the characteristic

Very little reverse current. Forward current rises rapidly after a threshold. This is an idealised characteristic.

P02.11 Thermistor

(F) (H) (T)

Resistance decreases as temperature increases; useful in temperature sensing.

P02.12 LDR

(F) (H) (T)

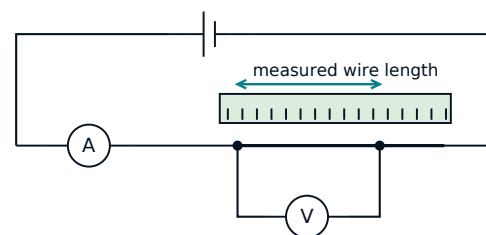
Resistance decreases as light intensity increases; useful in light-controlled circuits.

Circuits and electrical quantities

P02.13 RP Com 15 / Phys 03: wire resistance

(F) (H) (T)

Measure V and I for different wire lengths and calculate R. Keep material, diameter and temperature constant; switch off between readings.



Move the contact

Measure the tested length between the voltage connections. Keep wire material, diameter and temperature constant; switch off between readings.

P02.14 RP Com 15 / Phys 03: resistor arrangements

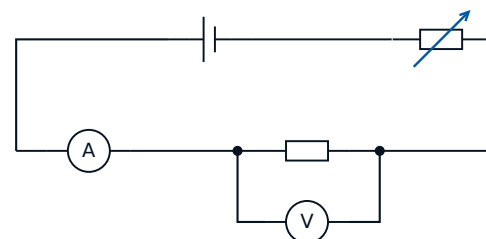
(F) (H) (T)

Measure equivalent resistance of series and parallel combinations using V/I; keep component/supply conditions comparable.

P02.15 RP Com 16 / Phys 04: I-V characteristics

(F) (H) (T)

Vary potential difference, record I and V, then reverse the supply for negative values. Investigate resistor, lamp and diode.



Correct meter placement

Ammeter: in series. Voltmeter: across the test component. Junction dots show electrical connections. Change potential difference using the variable resistor; reverse the supply for negative readings.

P02.16 RP Com 16 / Phys 04: precautions

(F) (H) (T)

Use low voltage, limit current (especially with a diode), and avoid unwanted temperature rise when testing an ohmic resistor.

P02 | Electricity

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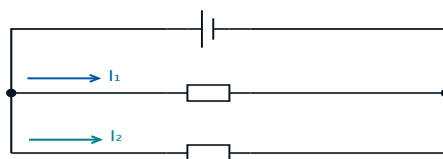
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Series and parallel

SERIES	PARALLEL
Current P02.17 (F H T) The same current flows through every component in a single loop.	P02.21 (F H T) Current splits between branches. Total current equals the sum of branch currents: $I_{\text{total}} = I_1 + I_2 + \dots$
Potential difference P02.18 (F H T) Supply potential difference is shared: $V_{\text{total}} = V_1 + V_2 + \dots$	P02.20 (F H T) Each branch has the same potential difference as the supply.
Resistance P02.19 (F H T) $R_{\text{total}} = R_1 + R_2 + R_3 + \dots$. Adding resistors increases total resistance.	P02.22 (F H T) Adding another conducting branch reduces total resistance; it is lower than the smallest individual branch resistance.



same V between the left and right junctions

Two complete branches

Each has the full supply potential difference. Current splits and rejoins: $I = I_1 + I_2$. Adding a conducting branch lowers total resistance.

Mains and appliances

P02.23 DC and AC (F H T)
Direct current flows one way; alternating current repeatedly reverses because the potential difference alternates.
DC: one direction AC: direction reverses

Mains and appliances

P02.24 (F H T) UK mains values	Approximately 230 V AC at 50 Hz.
P02.25 (F H T) Live wire	Brown insulation; carries the alternating supply potential difference, about 230 V relative to earth.
P02.26 (F H T) Neutral wire	Blue insulation; completes the circuit and is at or near 0 V.
P02.27 (F H T) Earth wire	Green/yellow insulation; normally carries no current and connects exposed metal to earth for fault protection. Protective route A low-resistance earth path allows a large fault current, causing the fuse to melt and disconnect live.
P02.28 (F H T) Live-wire danger	A connection from live to earth through a person can cause dangerous current; live can remain hazardous even when an appliance switch is open.
P02.29 (F H T) Electrical power	$P = VI$ and $P = I^2R$. P in W; V in volts; I in A; R in Ω .
P02.30 (F H T) Electrical energy	$E = QV$. E in J; Q in C; V in volts. For energy from power and time, rearrange P01's power equation.
P02.31 (F H T) Appliance transfers	Heaters increase thermal stores; motors increase kinetic stores. More power means more energy transferred each second.
National Grid	
P02.32 (F H T) National Grid	Cables and transformers linking electricity generation to consumers.

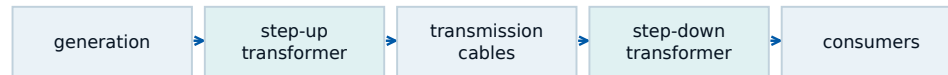
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National Grid

P02.33 Step-up / step-down

(F) (H) (T)

Step-up transformers increase transmission potential difference; step-down transformers reduce it before domestic use.



higher $V \rightarrow$ lower I for the same power

less power dissipated by heating in transmission cables (I^2R)

Transformers work with alternating current; diagram shows the transmission sequence.

P02.34 Why high voltage?

(F) (H) (T)

For a given transmitted power, higher voltage means lower current and less heating loss in cables (I^2R).

P02.35 Ideal transformer power

(H) (T)

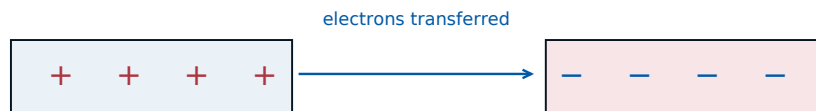
$V_p I_p = V_s I_s$, assuming input power = output power; p = primary, s = secondary. Voltage in V and current in A.

Static electricity

P02.T01 Charging by friction

(T)

Rubbing some insulators transfers electrons. The object gaining electrons becomes negative; the other loses electrons and becomes equally positive. Protons do not move between the objects.



loses electrons $\rightarrow$ positive

gains electrons $\rightarrow$ negative

Only electrons move between the materials; equal and opposite charges result.

P02.T02 Electrostatic forces

(T)

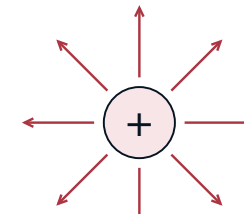
Like charges repel; opposite charges attract. Charged objects exert non-contact forces through electric fields.

Static electricity

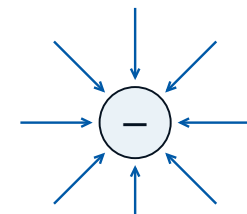
P02.T03 Electric field

(T)

A region where a charge experiences a force. Field direction is the force on a positive test charge; lines point away from a positive sphere and towards a negative sphere.



positive sphere: outwards



negative sphere: inwards

P02.T04 Field strength and sparking

(T)

The field becomes weaker farther from a charge. A sufficiently strong field can ionise air so charge flows across a gap, causing a spark.

P03 | Particle model of matter

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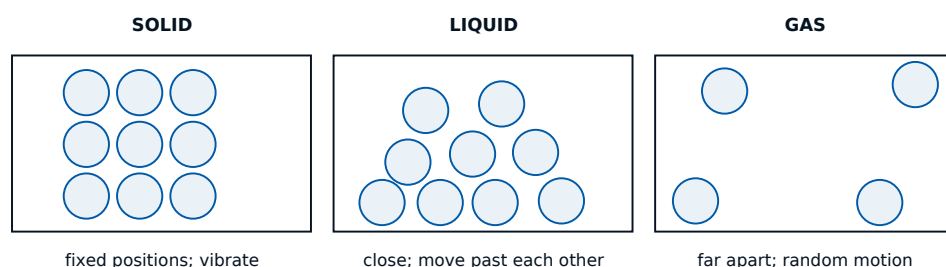
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Particles and density

P03.01	F H T	Close together in a regular arrangement, vibrating about fixed positions; fixed shape and volume.
P03.02	F H T	Close together but irregular; move past each other. Fixed volume but take the container's shape.

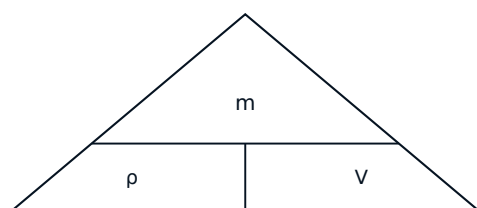
P03.03 Gas particles **F H T**

Widely separated, moving rapidly and randomly; no fixed shape or volume and easily compressed.



P03.04 Density **F H T**

$\rho = m/V$. ρ in kg/m^3 ; mass m in kg ; volume V in m^3 . It describes mass per unit volume.



Use the equation and check units.

Rearrangement reminder

$m = \rho \times V$. Divide the top quantity by one lower quantity to find the other. Use the stated units.

P03.05	F H T	Greater spacing usually means lower density; gases are much less dense than liquids/solids. Particle mass also matters.
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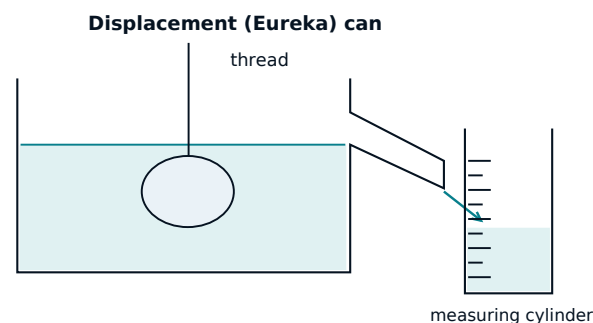
P03.06	F H T	Measure mass with a balance and dimensions with suitable instruments; calculate volume from geometry, then density.
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RP Com 17 / Phys 05: regular solid

Particles and density

P03.07 **RP Com 17 / Phys 05: irregular solid** **F H T**

RP Com 17 / Phys 05. Measure the mass of the dry solid. Students often use a displacement (Eureka) can: fill to the spout, let excess drain, then fully submerge the solid. Collect displaced water in a measuring cylinder; its volume equals the solid volume. Remove trapped air, then use density = mass/volume.



Before measuring

Fill to the spout and allow excess water to drain. Collect only the water displaced when the solid is fully submerged.

Volume of displaced water = volume of solid. $1 \text{ cm}^3 = 1 \text{ mL}$.

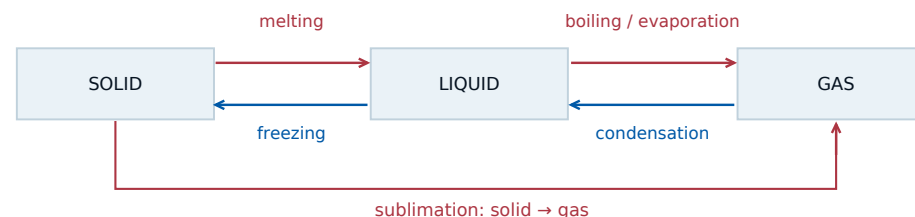
P03.08	F H T	Find mass by subtracting empty-container mass from filled mass; measure liquid volume and calculate density. Read the meniscus at eye level.
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RP Com 17 / Phys 05: liquid

P03.09 **Changes of state** **F H T**

Melting: solid→liquid; freezing: liquid→solid; boiling/evaporation: liquid→gas; condensation: gas→liquid; sublimation: solid→gas.

Same particles and total mass; only arrangement and motion change.



P03.10	F H T	Changing state creates no new substance; mass is conserved, and reversing the change restores the original material.
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Physical change

Internal energy and heating

P03.11	F H T	Total kinetic and potential energy of all the particles in a system.
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Internal energy

P03 | Particle model of matter

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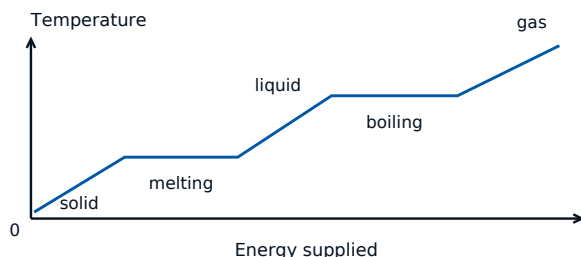
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Internal energy and heating

P03.12	(F)(H)(T)	Related to the average kinetic energy of particles; it is not the same as total internal energy.
P03.13	(F)(H)(T)	Can raise particle kinetic energy and temperature, or change particle arrangement during a state change. Specific heat capacity has its home in P01.
P03.14	(F)(H)(T)	Energy required to change the state of 1 kg without changing its temperature; unit J/kg.
P03.15	(F)(H)(T)	$E = mL$. E in J; m in kg; L in J/kg.
P03.16	(F)(H)(T)	Specific latent heat of fusion applies to melting/freezing; vaporisation to boiling/condensing.
P03.17	(F)(H)(T)	Heating-curve plateau

Temperature stays constant during a state change even as energy transfers; energy changes particle potential energy.



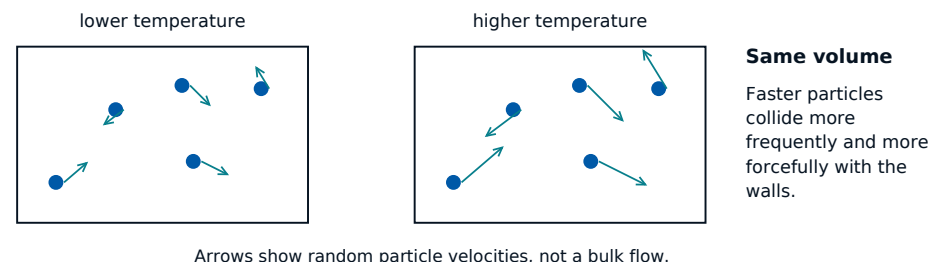
Pure substance, fixed pressure

Slopes: temperature rises.
Plateaus: state changes at constant temperature; energy changes particle potential energy.

Gas pressure

P03.18 Gas pressure mechanism (F)(H)(T)

Moving particles collide with container walls and exert forces; many collisions produce pressure.

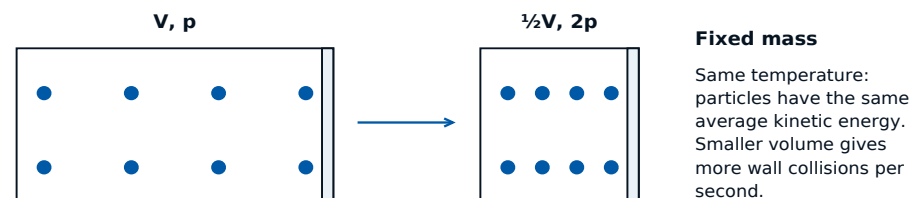


P03.19	(F)(H)(T)	At constant volume, higher temperature means faster particles and more forceful/frequent wall collisions, increasing pressure.
		Heating a sealed rigid container

Gas pressure and volume

P03.T01 Pressure and volume (T)

At constant temperature, compressing a fixed mass of gas increases wall-collision frequency and pressure. Expanding it reduces pressure; pressure acts normal to surfaces.



Pressure $\times$ volume stays constant only under the stated conditions.

P03.T02	(T)	Gas pressure equation	$p_1V_1 = p_2V_2$ for a fixed mass at constant temperature. Use matching pressure and volume units on both sides; SI units are Pa and m ³ .
P03.T03	(T)	Gas-volume example	A sealed gas at 100 kPa occupies 60 cm ³ . At constant temperature, compressing to 20 cm ³ gives $p_2 = 100 \times 60/20 = 300$ kPa.
P03.T04	(T)	Doing work on a gas	A force compressing a gas transfers energy to its internal store and can raise its temperature. A bicycle pump can warm during rapid pumping.

P04 | Atomic structure and radiation

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MY RETRIEVAL PRACTICE

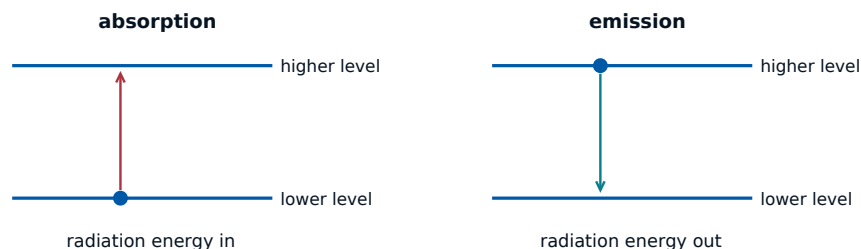
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Atomic links and energy levels

P04.01 **Shared atomic content** (F) (H) (T) Particle charges/masses, atomic and mass numbers, isotopes and the historical atom models are in C01. These facts are also examinable in Physics 1.

P04.02 **Electron energy changes** (F) (H) (T)

Absorbing electromagnetic radiation can move an electron to a higher energy level; falling to a lower level emits radiation.



P04.03 **Ionisation** (F) (H) (T) Removing electrons forms ions; ionising radiation can damage molecules in living cells.

Nuclear radiation

P04.04 **Radioactive decay** (F) (H) (T) A random change in an unstable nucleus that emits radiation as it becomes more stable. Individual decay times cannot be predicted.

P04.05 **Activity** (F) (H) (T) Number of nuclear decays per second; measured in becquerels, Bq.

P04.06 **Count rate** (F) (H) (T) Number of detections per second/minute recorded by an instrument; it need not equal the source's activity.

P04.07 **Alpha particle** (F) (H) (T) Two protons and two neutrons (a helium nucleus); strongly ionising, range of a few cm in air, stopped by paper/skin.

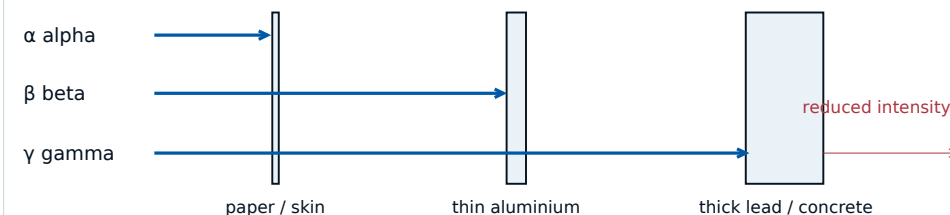
P04.08 **Beta-minus particle** (F) (H) (T) A fast electron emitted as a neutron in the nucleus changes to a proton; moderate ionisation, range of metres in air, stopped by thin aluminium.

Nuclear radiation

P04.09 **Gamma ray** (F) (H) (T)

Electromagnetic radiation from the nucleus; weakly ionising but highly penetrating. Thick lead or concrete reduces its intensity; it is not completely stopped.

schematic penetration; gamma is attenuated, not fully stopped



P04.10 **Neutron emission** (F) (H) (T) A neutron is emitted from the nucleus; it is uncharged.

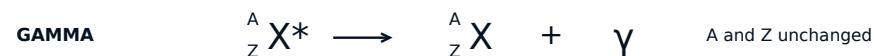
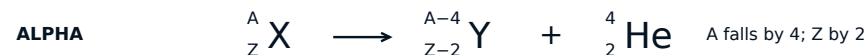
P04.11 **Alpha nuclear change** (F) (H) (T) Mass number decreases by 4; atomic number decreases by 2. Alpha symbol: ${}^4_2\text{He}$.

P04.12 **Beta-minus nuclear change** (F) (H) (T) Mass number unchanged; atomic number increases by 1. Beta symbol: ${}^0_{-1}\text{e}$.

P04.13 **Gamma nuclear change** (F) (H) (T) Neither mass number nor atomic number changes.

P04.14 **Balancing nuclear equations** (F) (H) (T)

Conserve total mass numbers and atomic numbers on each side; alpha and beta changes identify the missing numbers.



A = mass number; Z = atomic number; X* = excited nucleus.

P04 | Atomic structure and radiation

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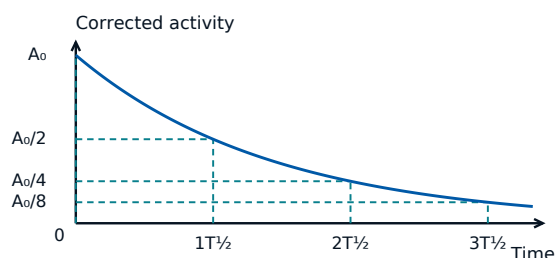
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Half-life and hazards

P04.15 Half-life

(F) (H) (T)

Time for the number of undecayed nuclei, activity or corrected count rate of a sample to halve.



Equal time intervals

Activity halves in each half-life. Subtract background count rate before using measured counts to estimate decay.

P04.16 Background correction

(F) (H) (T)

Subtract the background count rate before using source measurements for decay/half-life analysis.

P04.17 Repeated half-lives

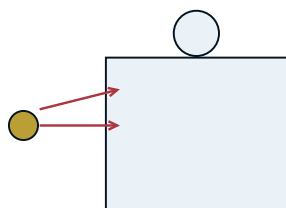
(H) (T)

Remaining fraction after n half-lives = $(\frac{1}{2})^n$; fraction decayed = $1 - (\frac{1}{2})^n$.

P04.18 Contamination

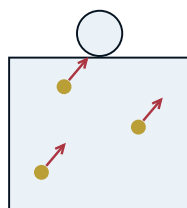
(F) (H) (T)

Unwanted radioactive material on or inside an object; radiation continues while that material remains.



IRRADIATION

external source irradiates the person



CONTAMINATION

radioactive material is on / inside the person

P04.19 Irradiation

(F) (H) (T)

Exposure to radiation from a source; the exposure itself does not make the object radioactive in these GCSE contexts.

P04.20 Inside / outside risk

(F) (H) (T)

Alpha is particularly hazardous inside the body; penetrating beta/gamma can also pose external hazards. Risk depends on dose and exposure.

P04.21 Reducing exposure

(F) (H) (T)

Minimise time, increase distance and use appropriate shielding; prevent ingestion/inhalation and handle sources with suitable tools.

Half-life and hazards

P04.22 Choosing a source

(F) (H) (T)

Match penetration and half-life to the purpose; consider whether the source is inside/outside the body and the necessary exposure duration.

P04.23 Radiation evidence

(F) (H) (T)

Studies should be published and peer reviewed so methods, results and conclusions can be checked.

Background radiation and medical uses

P04.T01 Background sources

(T)

Natural sources include radioactive rocks and cosmic rays. Human sources include nuclear fallout and some medical exposures. Location and occupation affect received dose.

P04.T02 Radiation dose

(T)

Dose information describes potential biological harm. The unit is sievert (Sv); $1000 \text{ mSv} = 1 \text{ Sv}$. Compare dose, exposure time and likely benefit when evaluating a use.

P04.T03 Half-life and hazard

(T)

For equal starting numbers of nuclei, a shorter half-life means higher initial activity but faster decline. A long half-life can keep material hazardous for much longer; type, amount and exposure also matter.

P04.T04 Medical tracers

(T)

A tracer should emit radiation detectable outside the body, often gamma, with a half-life long enough for the test but short enough to limit prolonged exposure. It must also be suitable for the body.

P04.T05 Radiotherapy

(T)

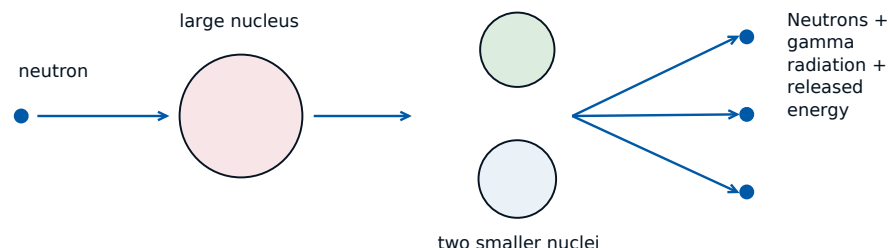
Radiation damages cancer cells; beams can target a tumour from different directions to concentrate dose there. Healthy tissue can also be damaged, so dose and targeting require control.

Fission and fusion

P04.T06 Nuclear fission

(T)

A large unstable nucleus, such as uranium, absorbs a neutron and splits into two smaller nuclei. Energy, gamma radiation and usually two or three neutrons are released; products have kinetic energy.



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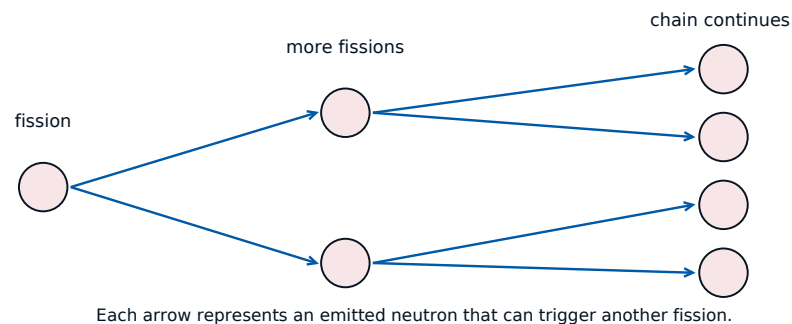
Fission and fusion

P04.T07

Chain reaction

T

Released neutrons cause further fissions. In a reactor, control rods absorb neutrons and a moderator slows them; controlling the rate controls energy release.

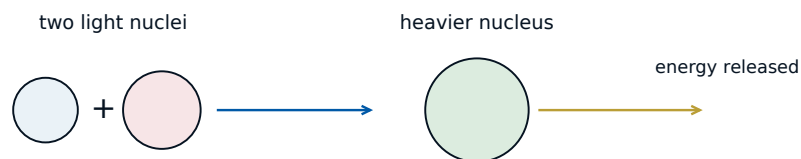


P04.T08

Nuclear fusion

T

Two light nuclei join to form a heavier nucleus, releasing energy as a small amount of mass is converted. High temperature and pressure help nuclei overcome repulsion.



High temperature and pressure help positively charged nuclei approach closely enough to fuse.

P04.T09

T

Fission versus fusion

Fission splits a heavy nucleus; fusion joins light nuclei. Both change nuclei and can release energy; neither is a chemical reaction involving only electron rearrangement.

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Forces and vectors		
P05.01	(F)(H)(T)	A quantity with magnitude only, such as mass, time, distance or speed.
Scalar		
P05.02	(F)(H)(T)	A quantity with magnitude and direction, such as force, displacement, velocity or acceleration. Arrow length represents magnitude.
Vector		
P05.03	(F)(H)(T)	Forces between touching objects: friction, drag, tension and normal contact force.
Contact forces		
P05.04	(F)(H)(T)	Gravity, electrostatic and magnetic forces act across a separation.
Non-contact forces		
P05.05	(F)(H)(T)	Mass is measured in kg; weight is the gravitational force, measured in N. Weight changes with gravitational field strength.
Mass and weight		
P05.06	(F)(H)(T)	$W = mg$. W in N; m in kg; g in N/kg. Weight acts through the centre of mass and can be measured with a newtonmeter.
Weight equation		
P05.07	(F)(H)(T)	A single force with the same effect as all the forces on an object combined; add signed forces along a straight line.
Resultant force		
P05.08		Free-body diagram (H)(T)
Shows only forces acting on the chosen object, with arrows indicating direction and relative magnitude.		
Balanced example Opposite arrows have equal lengths here. Resultant force is zero, so velocity stays constant; the object may still be moving.		

Forces and vectors		
P05.09		Resolving forces (H)(T)
Replace one force by perpendicular components with the same combined effect; use a scale vector drawing to find components/resultants.		
Vector addition The two perpendicular components have the same combined effect as the diagonal force. Use a scale drawing; arrowheads must meet head-to-tail.		
Work and springs		
P05.10	(F)(H)(T)	$W = Fs$ for displacement along the force's line of action. W in J; F in N; s in m. $1 \text{ J} = 1 \text{ N m}$.
Work done		
P05.11	(F)(H)(T)	Work against friction transfers energy to thermal stores and raises temperature.
Friction and energy		
P05.12	(F)(H)(T)	An object returns to its original shape when forces are removed.
Elastic deformation		
P05.13	(F)(H)(T)	The object does not fully return to its original shape after forces are removed.
Inelastic deformation		
P05.14	(F)(H)(T)	Extended length – original length; use metres in calculations.
Spring extension		
P05.15		Hooke's law (F)(H)(T)
$F = ke$ up to the limit of proportionality; F in N, k in N/m, e in m. Larger k means a stiffer spring. Beyond the elastic limit, removing the force leaves permanent deformation.		
P: limit of proportionality End of the straight-line region; $F = ke$ up to P. E: elastic limit Beyond E, the spring will not return to its original length when unloaded. Schematic: P and E are shown separately. A loading curve alone does not locate E.		

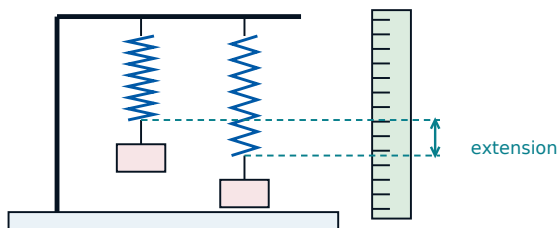
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Work and springs

P05.16	(F)(H)(T)	Point beyond which force is no longer directly proportional to extension; the F-e graph ceases to be straight.
P05.17	(F)(H)(T)	Work on an elastically stretched spring is stored as elastic potential energy; the equation has its home in P01.

P05.18 RP Com 18 / Phys 06: force and extension (F)(H)(T)

Add known forces to a clamped spring; measure extension from original length and plot force against extension.



Measure the change

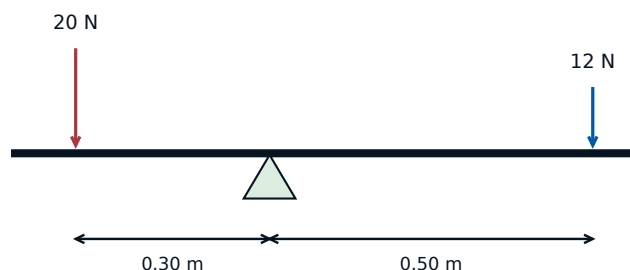
Loaded length minus original length. Read at eye level, use a fixed ruler and secure the stand.

P05.19	(F)(H)(T)	Keep a fixed ruler/fiducial marker, read at eye level, secure the stand and stay below damaging loads. In the straight region, gradient $F/e = k$.
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Moments, levers and gears

P05.T01 Moment of a force (T)

$M = Fd$. Moment M in $N\ m$; force F in N ; d is the perpendicular distance in metres from the pivot to the force's line of action.



Balanced

$$20 \times 0.30 = 12 \times 0.50 = 6\ N\ m$$

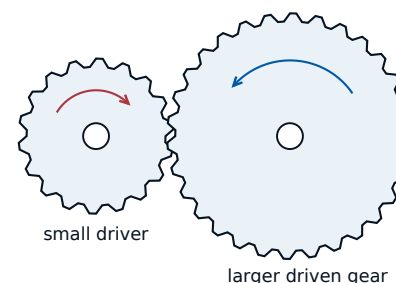
The distance is perpendicular to the force's line of action. The two moments are equal.

Moments, levers and gears

P05.T02	(T)	For rotational equilibrium, total clockwise moment = total anticlockwise moment about the same pivot. Example: 20 N at 0.30 m balances 12 N at 0.50 m.
P05.T03	(T)	A force farther from the pivot gives a larger moment. A longer effort arm can produce the required turning effect with a smaller force.

P05.T04 Gears (T)

Meshing gears rotate in opposite directions and transmit turning effects. A small driver turning a larger gear makes the output slower with a larger turning effect, ideally conserving power.



Opposite rotation

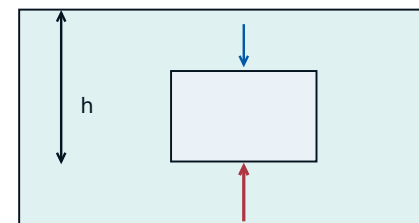
The teeth move together where they mesh. A larger driven gear turns more slowly with a greater turning effect.

Pressure in fluids

P05.T05	(T)	$p = F/A$. Pressure p in Pa, normal force F in N and area A in m^2 . The same force over a smaller area produces greater pressure.
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P05.T06 Pressure at depth (T)

$p = h\rho g$ gives the pressure due to a liquid column. Depth h in m, density ρ in kg/m^3 and g in N/kg give p in Pa. Greater depth or density gives greater pressure.



smaller downward force

larger upward force

upthrust

Pressure rises with depth: $p = h\rho g$. Equal side forces cancel.

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Pressure in fluids	
P05.T07 Upthrust	Pressure on the bottom of a submerged object is greater than pressure on its top, producing a resultant upward force. Its size equals the weight of displaced fluid.
P05.T08 Floating and sinking	An object floating at rest has upthrust equal to weight. If weight exceeds available upthrust it sinks; if upthrust exceeds weight it rises until forces balance or it reaches a boundary.
P05.T09 Atmospheric pressure	Air molecules collide with surfaces. At higher altitude there is less air above and lower air density, so atmospheric pressure decreases.
Motion	
P05.20 Distance / displacement	Distance / displacement
Distance is total path length; displacement is the straight-line change in position with direction.	
distance: total route Magnitude and direction Distance adds the whole path travelled. Displacement is the straight-line change from start to finish, with a direction.	
P05.21 Speed equation	Speed equation
$v = s/t$ for constant speed; average speed = total distance ÷ total time. v in m/s; s in m; t in s.	
Rearrangement reminder $s = v \times t$. Divide the top quantity by one lower quantity to find the other. Use the stated units.	
Use the equation and check units.	
P05.22 Typical speeds	Walking ≈ 1.5 m/s; running ≈ 3 m/s; cycling ≈ 6 m/s; sound in air ≈ 330 m/s. Values vary with conditions.

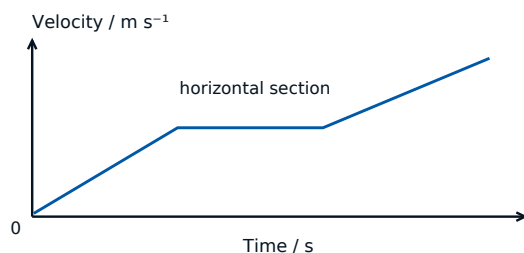
Motion	
P05.23 Velocity	Speed in a specified direction.
P05.24 Circular motion	An object at constant speed in a circle has changing velocity because direction changes; it is accelerating.
P05.25 Distance-time gradient	Distance-time gradient
Gradient gives speed. A horizontal line means stationary; a steeper line means greater speed.	
Read the vertical axis Distance-time: horizontal means stationary; gradient is speed.	
P05.26 Instantaneous speed	Instantaneous speed
Draw a tangent to a curved distance-time graph and calculate its gradient.	
Instantaneous speed Draw a tangent at the point. Use two well-separated points on the tangent to find its gradient.	
P05.27 Acceleration equation	Acceleration equation
$a = (v - u)/t$. a in m/s ² ; u and v in m/s; t in s. Deceleration is a reduction in speed.	

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Motion

P05.28 Velocity-time gradient (F) (H) (T)

Gradient gives acceleration. A horizontal line means constant velocity, not necessarily zero velocity.

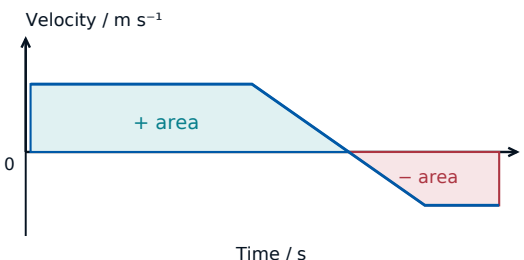


Read the vertical axis

Velocity-time: horizontal means constant velocity; gradient is acceleration.

P05.29 Velocity-time area (H) (T)

Signed area gives displacement; sum of absolute areas gives distance travelled.



Signed area

Displacement = positive area – magnitude of negative area. Total distance adds the magnitudes of both areas.

P05.30 (F) (H) (T) Uniform-acceleration equation

$v^2 - u^2 = 2as$; applies to constant acceleration. v, u in m/s ; a in m/s^2 ; s in m .

P05.31 (F) (H) (T) Free fall

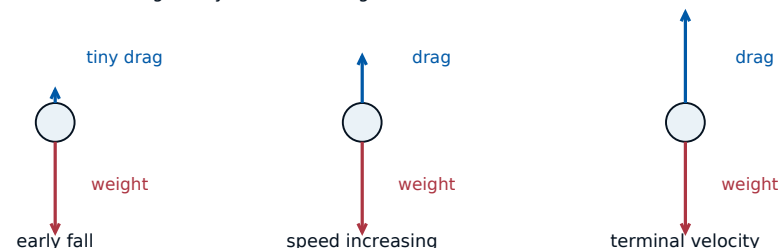
Near Earth, acceleration is about 9.8 m/s^2 when only gravity acts.

Motion

P05.32 Terminal velocity (F) (H) (T)

As speed rises, drag increases until it balances weight; resultant force and acceleration become zero.

Weight stays constant; drag rises until the two forces balance.



Newton's laws

P05.33 (F) (H) (T) **Newton's first law** With zero resultant force, an object stays at rest or continues at constant velocity.

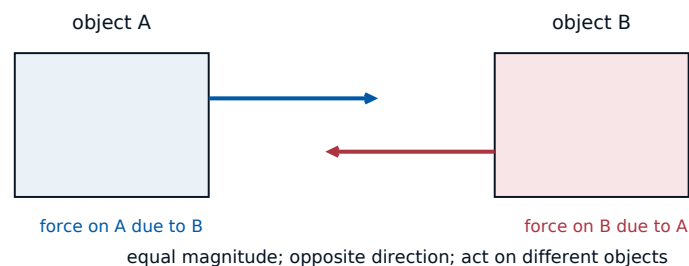
P05.34 (H) (T) **Inertia** The tendency to remain at rest or in uniform motion unless a resultant force acts.

P05.35 (F) (H) (T) **Newton's second law** $F = ma$, using resultant force. F in N ; m in kg ; a in m/s^2 .

P05.36 (H) (T) **Inertial mass** Ratio of resultant force to acceleration (F/a); measures resistance to a change in velocity.

P05.37 (F) (H) (T) Newton's third law

When two objects interact, they exert equal and opposite forces of the same type on each other. The forces act on different objects.



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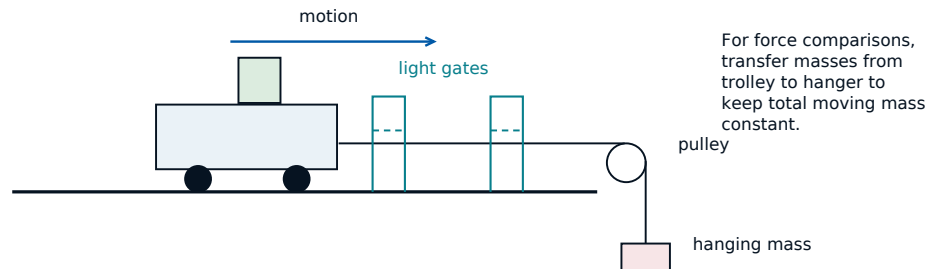
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Newton's laws

P05.38 RP Com 19 / Phys 07: acceleration and force

(F) (H) (T)

Vary pulling force while keeping total moving mass constant; measure acceleration, for example using light gates.



P05.39 (F) (H) (T) RP Com 19 / Phys 07: acceleration and mass

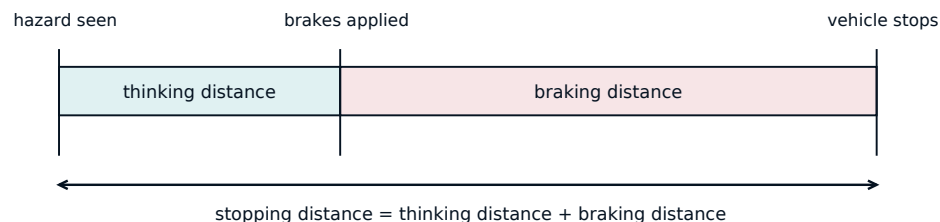
Vary total moving mass at constant resultant force; acceleration decreases as mass rises. Keep track/surface conditions consistent and account for friction.

Stopping and momentum

P05.40 Stopping distance

(F) (H) (T)

Thinking distance + braking distance.



P05.41 (F) (H) (T) Thinking distance

Distance travelled while the driver reacts; increases with speed and reaction time. Reaction-time facts/practical are in B05.

P05.42 (F) (H) (T) Reaction-time factors

Tiredness, alcohol, drugs and distractions can delay responses, increasing thinking distance.

P05.43 (F) (H) (T) Braking-distance factors

Higher speed, wet/icy roads and worn brakes/tyres increase braking distance; greater mass increases energy to remove at the same speed.

Stopping and momentum

P05.44 (F) (H) (T) Braking energy

Friction reduces kinetic energy and heats brakes. Large deceleration needs large force and can cause overheating or loss of control.

P05.45 (H) (T) Braking estimates

Use kinetic energy and work done to estimate average braking force; state assumptions about speed, mass and stopping distance.

P05.46 (H) (T) Momentum

$p = mv$. p in kg m/s; m in kg; velocity v in m/s. Include direction/sign.

P05.47 (H) (T) Momentum conservation

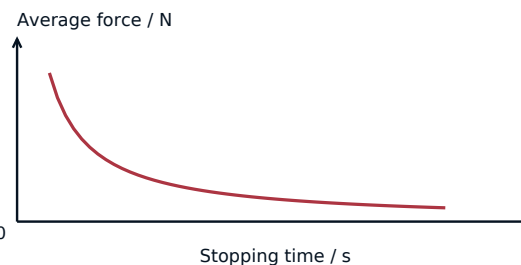
Total momentum before = total momentum after in a closed system with no external resultant force.

Changing momentum

P05.T10 Force and momentum change

(T)

$F = \Delta p / \Delta t = m \Delta v / \Delta t$ for constant mass. Force in N; momentum change in kg m/s; time in s. Keep velocity signs consistent.



Same momentum change

$F = \Delta p / \Delta t$. Longer stopping time means smaller average force. The graph is schematic.

P05.T11 (T) Impact protection

Airbags, seatbelts, helmets and crash mats increase the time over which momentum changes. For the same momentum change, a longer stopping time reduces average force.

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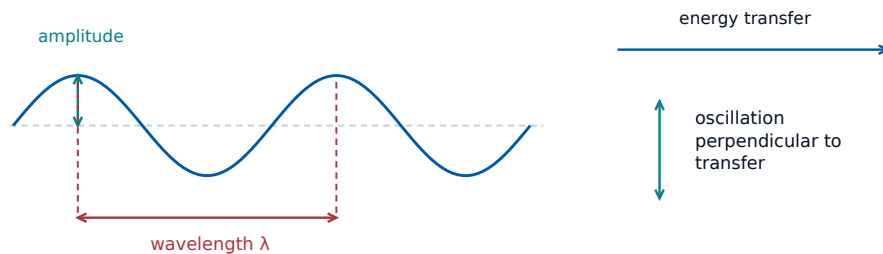
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Wave properties

P06.01 **Wave transfer** (F) (H) (T) Waves transfer energy without an overall transfer of the medium's material.

P06.02 **Transverse wave** (F) (H) (T)

Oscillations are perpendicular to the direction of energy transfer; examples include surface ripples and electromagnetic waves.



P06.03 **Longitudinal wave** (F) (H) (T)

Oscillations are parallel to energy transfer; compressions and rarefactions travel through the medium, as in sound.



P06.04 **Amplitude** (F) (H) (T) Maximum displacement from the undisturbed position.

P06.05 **Wavelength, λ** (F) (H) (T) Distance between equivalent points on adjacent waves, such as crest to crest; unit m.

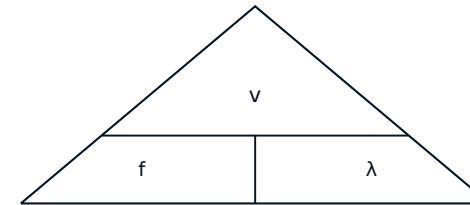
P06.06 **Frequency, f** (F) (H) (T) Number of complete waves passing a point per second; unit Hz.

P06.07 **Period equation** (F) (H) (T) $T = 1/f$. T in s; f in Hz.

Wave properties

P06.08 **Wave-speed equation** (F) (H) (T)

$v = f\lambda$. v in m/s; f in Hz; λ in m.



Use the equation and check units.

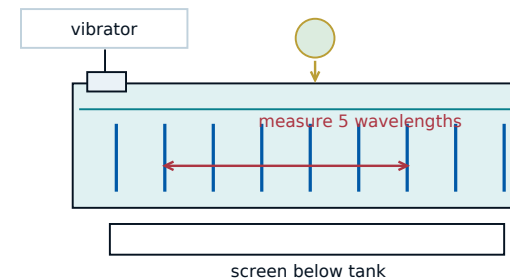
Rearrangement reminder

$v = f \times \lambda$. Divide the top quantity by one lower quantity to find the other. Use the stated units.

P06.09 **Measuring sound speed** (F) (H) (T) Measure travel time over a known distance, or time delay between spaced microphones; speed = distance/time. Use a long distance to reduce timing error.

P06.10 **RP Com 20 / Phys 08: ripple tank** (F) (H) (T)

Use a lamp/screen to observe ripples; measure several wavelengths and divide, measure frequency and use $v = f\lambda$.



Measure several spacings

Divide total distance by the number of wavelengths. Combine λ with the measured frequency to find wave speed.

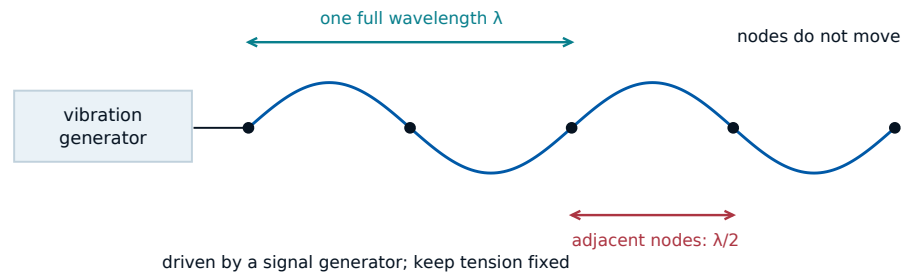
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Wave properties

P06.11 RP Com 20 / Phys 08: waves in a solid

(F) (H) (T)

Use a vibrating string and signal generator; measure repeated wavelengths and frequency. Control tension and avoid confusing half-wavelength segments with full wavelengths.

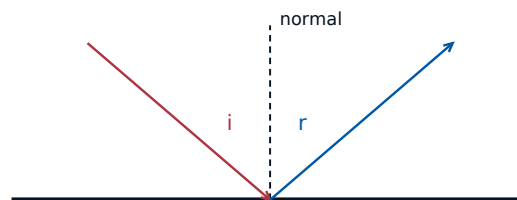


Reflection and the light practical

P06.T01 Reflection law

(T)

Angle of incidence = angle of reflection, measured between each ray and the normal (90° to the surface). Arrowheads show the direction light travels.



$$i = r$$

Both angles are measured from the normal, not from the reflecting surface.

The incident ray, reflected ray and normal lie in the same plane.

P06.T02 (T) Wave boundaries

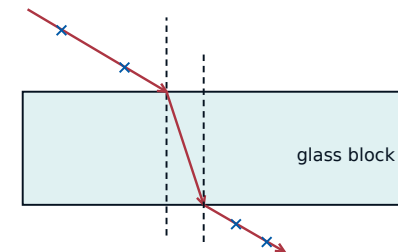
At an interface, some wave energy may be reflected, transmitted or absorbed. Absorbed energy is transferred to the material.

Reflection and the light practical

P06.T03 RP Phys 09: reflection and refraction

(T)

Trace a narrow ray from a ray box onto a surface or transparent block. Mark the boundary and ray positions, remove the apparatus, draw rays and normals, then measure angles with a protractor.



Mark then draw

Trace the block. Mark two points on each external ray. Join with a ruler, add normals and measure angles.

P06.T04 (T)

RP Phys 09: comparison and care

Compare several incidence angles and different surfaces or materials while keeping the method consistent. Thin rays and widely spaced position marks improve precision; avoid shining light into eyes.

Sound, ultrasound and seismic waves

P06.T05 (T) Sound and hearing

Sound vibrations can travel through solids. Sound makes the eardrum and other ear structures vibrate; the transfer works over a limited frequency range. Normal human hearing is roughly 20 Hz-20 kHz.

P06.T06 (T) Ultrasound

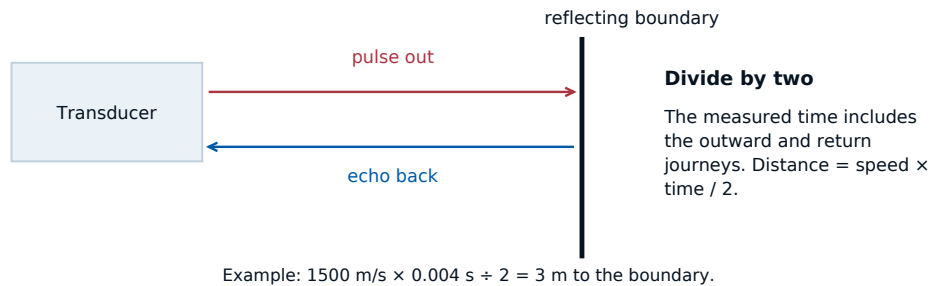
Sound above 20 kHz is beyond normal human hearing. Partial reflections at tissue or material boundaries can locate structures in medical scans and industrial flaw detection.

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Sound, ultrasound and seismic waves

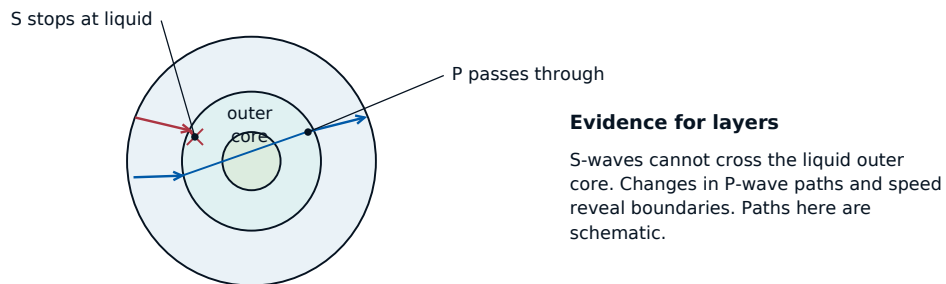
P06.T07 Echo distance (T)

Distance to a reflecting boundary = wave speed $\times$ return time $\div$ 2. Divide by two because the pulse travels to the boundary and back.



P06.T08 Seismic evidence (T)

P-waves are longitudinal and pass through solids and liquids; S-waves are transverse and do not pass through liquids. Their paths and missing arrivals provide evidence for a liquid outer core.



P06.T09 Echo sounding (T)

A high-frequency pulse sent from a ship reflects from the seabed or an object. Its return time gives depth or distance when the speed in water is known.

Electromagnetic spectrum

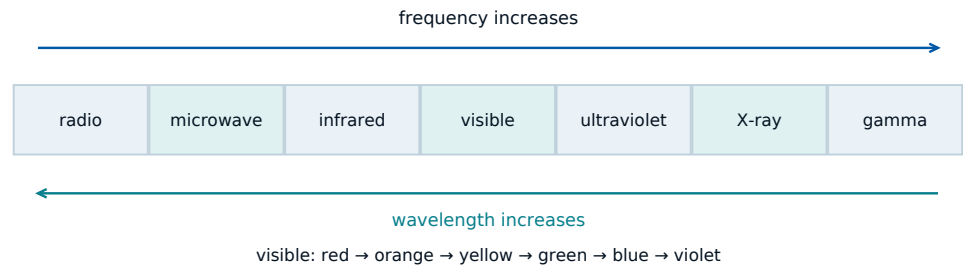
P06.12 EM waves (F)(H)(T)

Transverse waves that can travel through a vacuum; all have the same speed in vacuum, about $3 \times 10^8 \text{ m/s}$.

Electromagnetic spectrum

P06.13 Spectrum order (F)(H)(T)

Radio $\rightarrow$ microwave $\rightarrow$ infrared $\rightarrow$ visible (red to violet) $\rightarrow$ ultraviolet $\rightarrow$ X-ray $\rightarrow$ gamma; frequency increases and wavelength decreases.

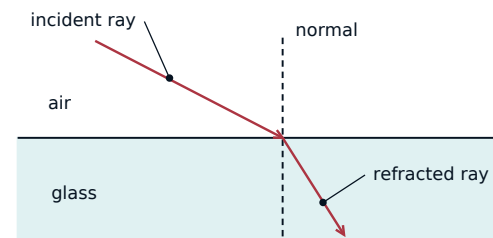


P06.14 Visible light (F)(H)(T)

The limited part of the EM spectrum detected by human eyes.

P06.15 Refraction diagram (F)

Draw the incident and refracted rays at the boundary, with arrowheads. Add a normal at 90° to the boundary and measure each angle from this normal.



Draw and label

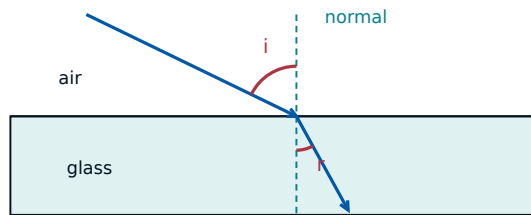
Use a ruler. Add a normal at right angles to the boundary. Ray arrows show the direction of light travel.

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Electromagnetic spectrum

P06.R01 Refraction: change of speed (H) (T)

A ray changes direction at a boundary when it enters at an angle and changes speed; measure angles from the normal.



Angles from the normal

The ray slows and bends towards the normal on entering glass at an angle. For this example, r is smaller than i .

P06.16 (H) (T) Refraction mechanism

Frequency stays constant across the boundary; a speed change changes wavelength. Slower entry bends towards the normal; faster entry bends away.

P06.17 (H) (T) Wave interactions

Absorption, transmission, reflection and refraction depend on material and wavelength.

P06.18 (H) (T) Radio-wave generation

Oscillating currents generate radio waves; absorbed radio waves can induce alternating currents at the same frequency.

P06.19 (F) (H) (T) EM origins

Energy changes in atoms can emit/absorb EM waves; changes in nuclei can produce gamma rays.

P06.20 (F) (H) (T) Radio / microwave uses

Radio: TV/radio communication. Microwaves: satellite communication and cooking.

P06.21 (F) (H) (T) Infrared / visible uses

Infrared: heaters, cooking and thermal cameras. Visible: vision and fibre-optic communication.

P06.22 (F) (H) (T) UV / X-ray / gamma uses

UV: fluorescent lamps and tanning; X-rays: medical imaging; gamma: imaging and cancer treatment.

P06.23 (H) (T) Suitability for uses

Microwaves can pass through the atmosphere; IR transfers thermal energy; X-rays pass through soft tissue more readily than bone; gamma penetrates tissue.

P06.24 (F) (H) (T) Radiation hazards

UV can age skin and increase skin-cancer risk; X-rays and gamma ionise molecules, potentially causing mutations and cancer.

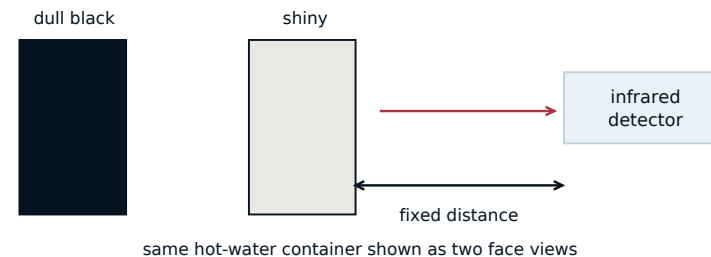
Electromagnetic spectrum

P06.25 (F) (H) (T) Dose

A measure of exposure risk; interpret dose data carefully. $1000 \text{ mSv} = 1 \text{ Sv}$. AQA does not require recall of this unit.

P06.26 (F) (H) (T) RP Com 21 / Phys 10: absorption/emission

Compare surfaces while controlling temperature, area, distance and surroundings. Dull black is a better infrared absorber/emitter than shiny surfaces.



Compare fairly

Move the detector to the same distance from each equal-temperature face. Keep area and surroundings the same.

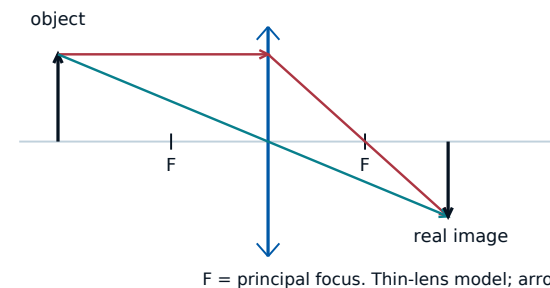
P06.27 (F) (H) (T) RP Com 21 / Phys 10: measurements

Measure detector readings from equal-temperature surfaces, or temperature rise under equal irradiation. Repeat and avoid touching hot apparatus.

Lenses and visible light

P06.T10 (T) Converging lens

A convex lens brings parallel rays to a principal focus. Focal length is the lens-to-focus distance. A ray through the optical centre continues straight in the thin-lens model.



CONVEX

Parallel ray $\rightarrow$ far focus; central ray goes straight. Their intersection locates a real, inverted image.

F = principal focus. Thin-lens model; arrows show light direction.

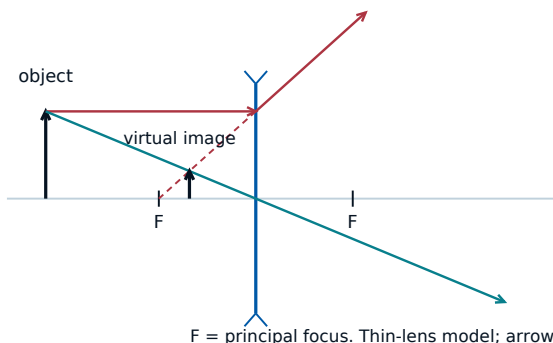
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Lenses and visible light

P06.T11 Diverging lens

A concave lens spreads parallel rays as if they came from the principal focus on the incident side. Backward extensions locate a virtual image.



CONCAVE

The emerging ray diverges. Trace it backwards: rays appear to come from a smaller upright virtual image.

F = principal focus. Thin-lens model; arrows show light direction.

P06.T12 Real and virtual images

A real image forms where rays meet and can be projected onto a screen. A virtual image is where rays appear to originate; it cannot be projected directly onto a screen.

P06.T13 Convex-lens image cases

Outside 2F: smaller, real and inverted. At 2F: same size, real and inverted. Between F and 2F: larger, real and inverted. Inside F: larger, virtual and upright. At F, emerging rays are parallel.

OBJECT POSITION

IMAGE

Beyond 2F	Real • inverted • smaller
At 2F	Real • inverted • same size
Between F and 2F	Real • inverted • larger
At F	Parallel output • no finite image
Inside F	Virtual • upright • larger

P06.T14 Concave-lens image

For a real object, the image is always virtual, upright and smaller, between the lens and near focus.

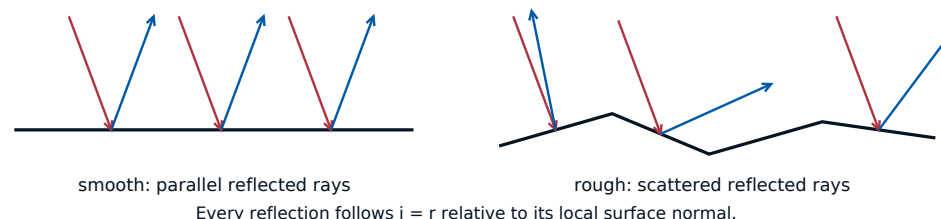
P06.T15 Lens magnification

Magnification = image height ÷ object height, with both heights in the same units. The ratio has no unit; use the sizes of the arrows in a ray diagram.

Lenses and visible light

P06.T16 Specular and diffuse reflection

A smooth surface reflects parallel incident rays in one direction. A rough surface has different local normals, so reflected rays scatter; the reflection law still holds at each point.

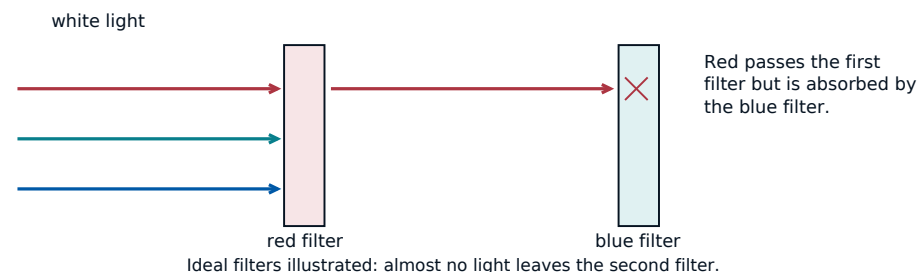


P06.T17 Colours of opaque objects

An object reflects some wavelengths and absorbs others. A red object reflects red light and absorbs much of the rest; it can look black in blue light. White reflects all visible colours; black absorbs them.

P06.T18 Colour filters

A filter transmits selected wavelengths and absorbs others. A red filter transmits red; two filters with no common transmitted wavelengths allow almost no light through.



P06.T19 Transparent and translucent

Transparent material transmits light with little scattering, allowing a clear image. Translucent material transmits but scatters light, so a clear image is not seen.

Black bodies and radiation balance

P06.T20 Perfect black body

Absorbs all incident radiation and reflects or transmits none. It is also the best possible emitter at a given temperature. All objects emit and absorb radiation.

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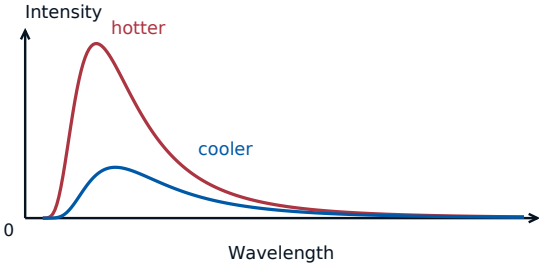
Black bodies and radiation balance

P06.T21

Temperature and emission

T

A hotter object emits more radiation per second. Its intensity distribution changes and the peak moves towards shorter wavelengths.



Hotter body

More radiation is emitted at every wavelength; the peak also moves to shorter wavelengths.

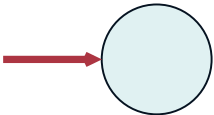
P06.T22

Radiation balance

T

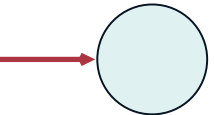
Constant temperature requires absorbed power to equal emitted power. Greater absorption than emission warms a body; greater emission cools it.

warming



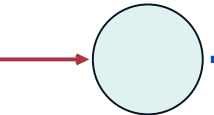
in > out

steady



in = out

cooling



in < out

Compare absorbed power (red) with emitted power (blue), not simply the number of rays.

P06.T23

Earth's temperature

T

Temperature depends on incoming solar radiation, reflection into space, absorption by surface and atmosphere, and emission to space. A changed balance shifts the temperature until balance is restored.

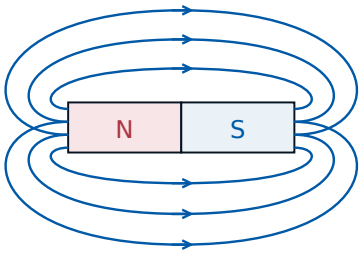
F Combined Foundation

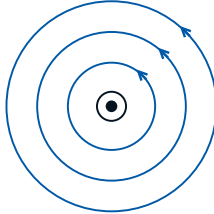
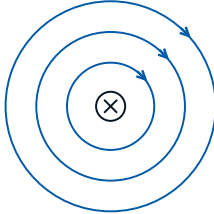
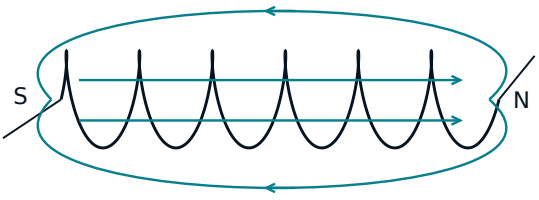
H Combined Higher

T Triple Higher

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Magnets and fields		
P07.01 Magnetic poles	F H T	Like poles repel; unlike poles attract. Magnetic forces are strongest near the poles.
P07.02 Permanent magnet	F H T	Produces its own persistent magnetic field.
P07.03 Induced magnet	F H T	Becomes magnetic in an external field and is attracted; often loses most magnetism when removed.
P07.04 Magnetic materials	F H T	Iron, steel, cobalt and nickel are attracted by magnets.
P07.05 Magnetic field	F H T	Region where magnetic forces act. Outside a magnet, field direction is from north to south.
 Field outside the magnet Direction is N → S. Lines do not cross. Closer lines represent a stronger field. This is a 2D slice through a 3D field.		
P07.06 Field-line spacing	F H T	Closer field lines represent a stronger field; lines do not cross.
P07.07 Compass	F H T	Its north-seeking pole aligns with the magnetic field; a compass can map direction at successive points.
P07.08 Earth's magnetism	F H T	Earth's magnetic field makes a freely turning compass align, providing evidence of a magnetic interior.

Electromagnets		
P07.09 Current in a straight wire	F H T	Produces circular magnetic field lines centred on the wire. Larger current strengthens the field; greater distance weakens it.
  Right-hand grip rule Thumb follows conventional current; curled fingers follow the magnetic field. Dot = arrow tip; cross = arrow tail.		
P07.10 Right-hand grip rule	F H T	Thumb points in conventional current direction; curled fingers give the field direction around a straight wire.
P07.11 Solenoid	F H T	A coil of wire whose field resembles a bar magnet; inside it the field is strong and approximately uniform.
 Field of a solenoid Strong and approximately uniform inside; returns N → S outside. Reverse the current to swap poles. Iron strengthens the field.		
P07.12 Stronger electromagnet	F H T	Increase current or turns per unit length; add an iron core.
P07.13 Reversing current	F H T	Reverses the magnetic field direction and swaps a solenoid's poles.
Motor effect		
P07.14 Motor effect	H T	A current-carrying conductor in a magnetic field experiences a force due to interaction of the fields.

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P07 | Magnetism and electromagnetism

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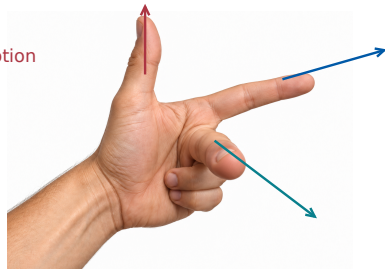
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Motor effect

P07.15 Fleming's left hand (H) (T)

Use your LEFT hand. First finger: magnetic field N→S. Second finger: conventional current. Thumb: force/motion. Hold all three at right angles to each other.

THUMB
Force / motion



FIRST FINGER
Magnetic field N → S

SECOND FINGER
Conventional current
Points towards you

LEFT HAND: three perpendicular directions, shown in perspective.

P07.16 (H) (T) Motor-force equation

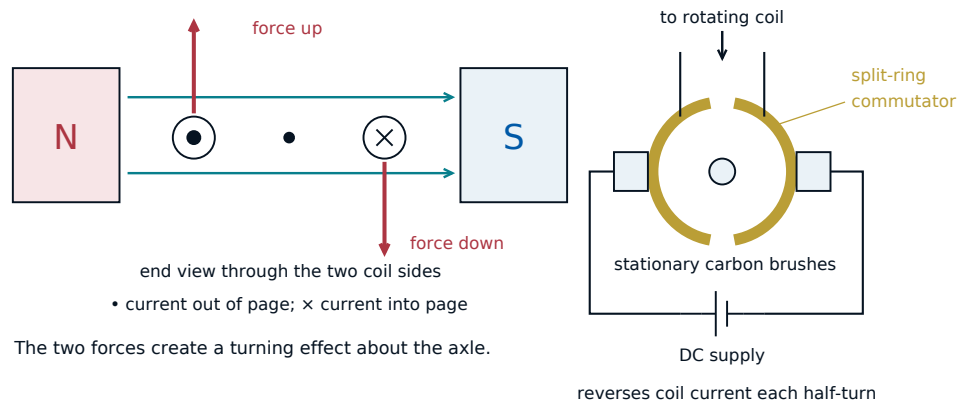
$F = BIl$ for a wire perpendicular to the field. F in N; B in T; I in A; length in the field l in m.

P07.17 (H) (T) Force changes

Greater B , I or active wire length gives greater force. Reverse current or field to reverse force; reversing both leaves force direction unchanged.

P07.18 Electric motor (H) (T)

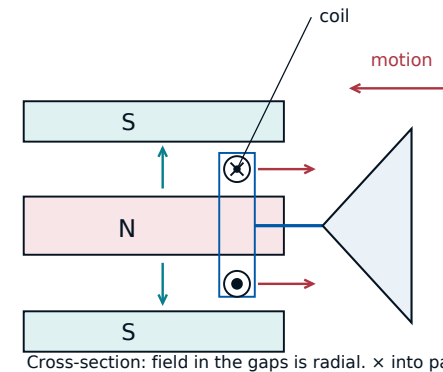
Opposite sides of a current-carrying coil experience opposite forces, producing rotation. A split-ring commutator reverses current each half-turn to sustain rotation.



Loudspeakers and induction

P07.T01 Moving-coil loudspeaker (T)

An alternating current in a coil within a permanent magnetic field produces a reversing force. The attached cone vibrates, creating pressure changes in air; headphones use the same motor effect.

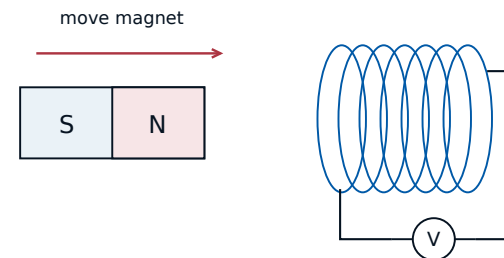


MOTOR EFFECT

Changing current reverses the force, moving the coil and cone back and forth along the axis.

P07.T02 Generator effect (T)

Relative motion between a conductor and magnetic field, or a changing magnetic field through a coil, induces a potential difference. A complete circuit permits an induced current.



Changing field

Motion induces a potential difference. Reverse motion or the magnet poles to reverse it; no relative change gives no sustained induced p.d.

P07.T03 (T) Larger induced potential

Move the conductor or magnet faster, use a stronger field, or use more coil turns to increase the change in field linked with the circuit.

P07.T04 (T) Induced direction

Reverse the motion or magnetic-field direction to reverse the induced potential difference. The induced current's field opposes the change that produced it.

P07 | Magnetism and electromagnetism

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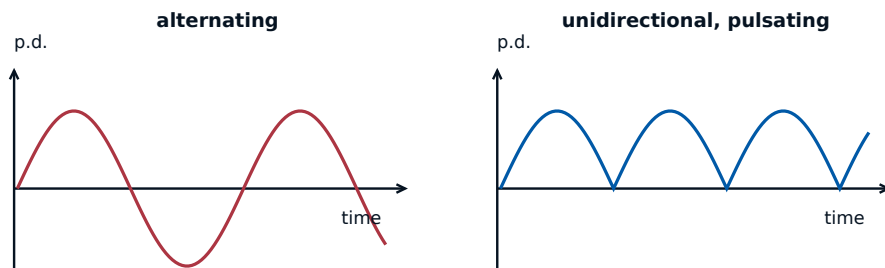
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Generators, microphones and transformers

P07.T05 Alternator and dynamo T

A rotating coil in a magnetic field induces a changing potential difference. Slip rings give alternating output; a split-ring commutator gives a unidirectional, pulsating output.

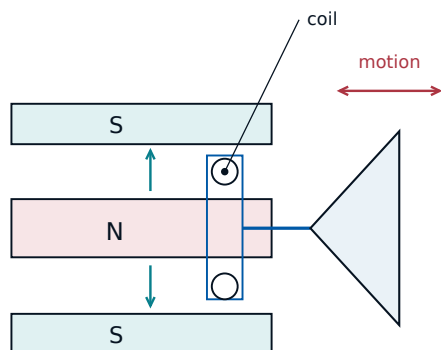


Alternator: slip rings

Dynamo: split-ring commutator

P07.T06 Moving-coil microphone T

Sound moves a diaphragm and attached coil in a magnetic field. The changing field linkage induces a varying potential difference and, in a circuit, current that represents the sound.



GENERATOR EFFECT

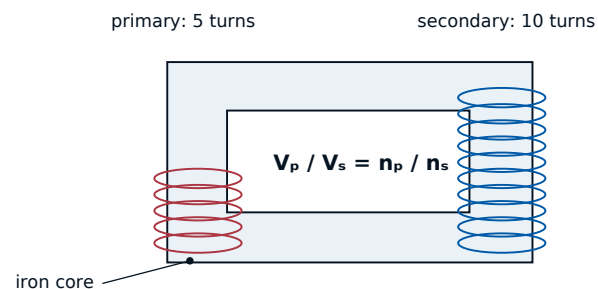
Sound moves the diaphragm and coil along the axis. Changing field linkage induces a varying p.d.

Cross-section: field in the gaps is radial. The generated electrical signal follows the vibration.

Generators, microphones and transformers

P07.T07 Transformer operation T

Alternating current in the primary creates a changing magnetic field in an iron core. This induces an alternating potential difference in the secondary. Steady direct current does not provide continuous transformation.



Step-up example

Twice as many secondary turns gives twice the potential difference. Ideal output current is half the input current at the same power.

P07.T08 T

Transformer turns equation

$V_p/V_s = n_p/n_s$. V is potential difference in volts; n is number of turns; p = primary and s = secondary. More secondary turns produce a higher secondary potential difference.

P07.T09 T

Transformer calculation

A 230 V primary with 1000 turns and a 50-turn secondary gives 11.5 V. At 100% efficiency, an output of 23 W draws $23/230 = 0.10$ A from the primary.

P07.T10 T

Transformer power home

The ideal-power equation $V_p I_p = V_s I_s$ is in P02. Raising transmission voltage reduces current for a given power, reducing $I^2 R$ heating losses in cables.

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Solar system and stars

P08.T01 Our solar system T

The Sun is its star. Eight planets and dwarf planets orbit the Sun; moons orbit planets. Our solar system lies within the Milky Way galaxy.

PLANETS IN ORDER FROM THE SUN



Sizes and distances not to scale. Moons and dwarf planets are not shown.

P08.T02 T Natural and artificial satellites

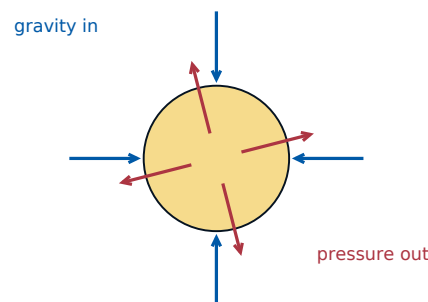
A moon is a natural satellite. An artificial satellite is placed in orbit by people. Both move under gravity; planets orbit stars.

P08.T03 T Star formation

Gravity pulls together gas and dust in a nebula. A contracting protostar becomes hotter and denser until hydrogen fusion begins.

P08.T04 Main-sequence equilibrium T

Inward gravitational attraction is balanced by outward pressure supported by energy from fusion. The star remains relatively stable while sufficient hydrogen fuel remains.



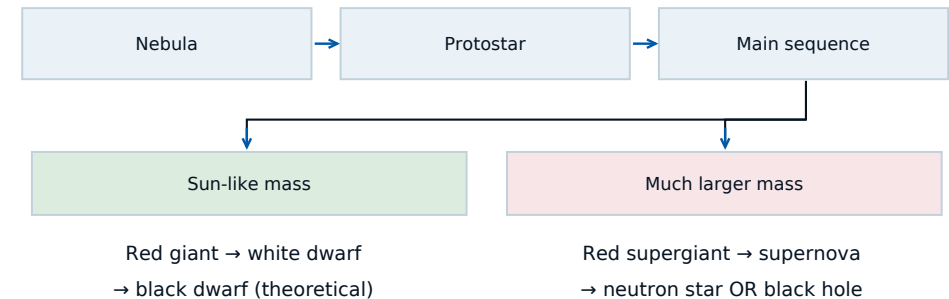
MAIN SEQUENCE

Inward gravity balances outward pressure supported by fusion energy. This is dynamic balance, with fusion continuing.

Solar system and stars

P08.T05 Sun-like star life cycle T

Nebula → protostar → main-sequence star → red giant → white dwarf → eventual black dwarf (a theoretical cooled remnant). The final cooling occurs over extremely long times.



A star's initial mass controls its evolutionary path; the timeline is not to scale.

P08.T06 T Massive star life cycle

Nebula → protostar → massive main-sequence star → red supergiant → supernova → neutron star or black hole, depending on the remnant's mass.

P08.T07 T Making and spreading elements

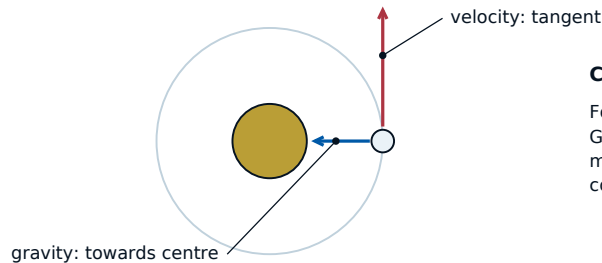
Fusion in stars builds heavier nuclei up to iron. In the AQA model, elements heavier than iron form in supernovae, which scatter material for later stars and planets.

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Orbits and the expanding universe

P08.T08 Circular orbits T

Gravity supplies an inward force perpendicular to instantaneous motion. Direction, and therefore velocity, continually changes even if speed stays constant.



Circular motion

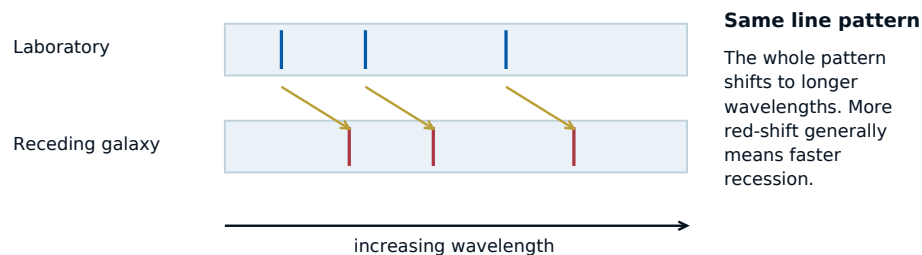
Force and velocity are perpendicular. Gravity changes the direction of motion, so velocity changes even at constant speed.

P08.T09 Orbital speed and radius T

For a stable circular orbit around a given body, a higher orbital speed corresponds to a smaller radius. A speed change requires a different orbit; simply speeding up does not preserve the same circular path.

P08.T10 Red-shift T

Spectral lines from a receding galaxy appear at longer wavelengths than matching laboratory lines. A larger red-shift generally indicates faster recession.



Same line pattern

The whole pattern shifts to longer wavelengths. More red-shift generally means faster recession.

P08.T11 Expansion evidence T

More distant galaxies generally show greater recession speeds. This pattern supports an expanding universe rather than expansion away from a special central place in space.

P08.T12 Big Bang model T

The universe developed from an extremely hot, dense early state. The observed expansion supports this model; scientists compare predictions with observations and revise explanations as evidence develops.

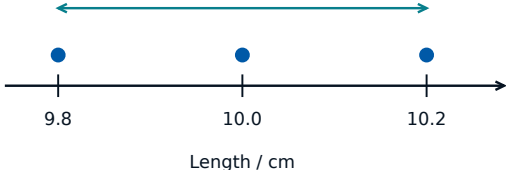
Orbits and the expanding universe

P08.T13 T	Supernova observations since 1998 indicate that expansion is accelerating. Dark energy is the name given to the unknown explanation in current models.
Accelerating expansion	
P08.T14 T	Dark matter is inferred from gravitational effects without detected light from it; dark energy concerns accelerated expansion. Their nature is still uncertain, illustrating the limits of current knowledge.
Unresolved questions	

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Scientific thinking		
S00.01	(F)(H)(T)	A testable proposed explanation or prediction.
Hypothesis		
S00.02	(F)(H)(T)	A representation used to explain/predict; evidence can reveal limitations and lead to revision.
Model		
S00.03	(F)(H)(T)	Other specialists scrutinise methods, evidence and conclusions before/after publication; it helps identify weaknesses.
Peer review		
S00.04	(F)(H)(T)	Two variables changing together does not establish that one causes the other; consider mechanisms and other variables.
Correlation / cause		
S00.05	(F)(H)(T)	Use evidence about likelihood and severity of harm alongside benefits, costs and ethical/environmental impacts.
Risk and benefit		
Investigations and measurements		
S00.06	(F)(H)(T)	The factor deliberately changed.
Independent variable		
S00.07	(F)(H)(T)	The factor measured in response.
Dependent variable		
S00.08	(F)(H)(T)	A factor kept constant so a comparison tests the intended variable.
Control variable		
S00.09	Accuracy (F)(H)(T)	
Closeness of a measurement to the true value.		
Repeated measurements of a known value		
accurate + precise true value small spread; close to true value precise, biased true value small spread; shifted from true value accurate mean, low precision true value large spread; mean near true value		
S00.10	(F)(H)(T)	Closeness of repeated measurements to each other.
Precision		
S00.11	(F)(H)(T)	The same person/method/equipment gives similar results.
Repeatability		
S00.12	(F)(H)(T)	Different people or methods obtain similar results.
Reproducibility		

Investigations and measurements		
S00.13	(F)(H)(T)	Unpredictable variation between measurements; repeats and a mean reduce its influence.
Random error		
S00.14	(F)(H)(T)	A consistent bias, such as a zero error; repeating measurements does not remove it.
Systematic error		
S00.15	(F)(H)(T)	A result unlike the pattern; investigate its cause before deciding whether to exclude it.
Anomaly		
S00.16	(F)(H)(T)	Smallest change it can detect/display. Choose a scale suited to the measurement.
Resolution of an instrument		
S00.17	Uncertainty from repeats (F)(H)(T)	
A simple estimate is $\pm$ half the range around the mean; state the method used.		
Illustrative repeated readings: 9.8, 10.0, 10.2 cm range = 0.4 cm  Mean $\pm$ half range Mean = 10.0 cm. Half range = 0.2 cm. Report 10.0 ± 0.2 cm using this stated estimate.		
S00.18	(F)(H)(T)	Identify hazard, who/how it could harm, and a control that reduces risk. Practical entries are recall summaries, not stand-alone laboratory instructions.
Risk assessment		
Maths and graphs		
S00.19	(F)(H)(T)	Mean: sum $\div$ number. Median: middle ordered value. Mode: most frequent value.
Mean / median / mode		
S00.20	(F)(H)(T)	100 $\times$ change $\div$ original value; use a sign to distinguish increase from decrease.
Percentage change		
S00.21	(F)(H)(T)	Change in vertical-axis quantity $\div$ change in horizontal-axis quantity. Include units.
Gradient		
S00.22	(F)(H)(T)	Use bars for categories; scatter/line plots for numerical relationships. Label each axis with quantity and unit.
Graph choice		

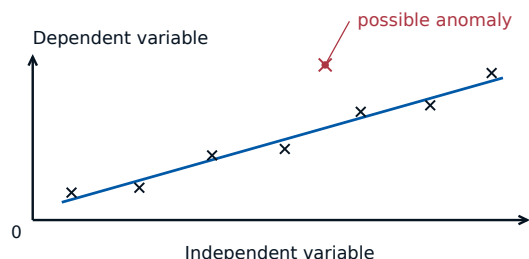
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Maths and graphs

S00.23 Best fit

(F) (H) (T)

Follow the trend using an appropriate line or curve; do not automatically join every point.



Follow the trend

A best-fit line balances the scatter. It need not pass through every point or the origin. Investigate an unusual result before excluding it. Add units for real variables.

S00.24 Direct proportion

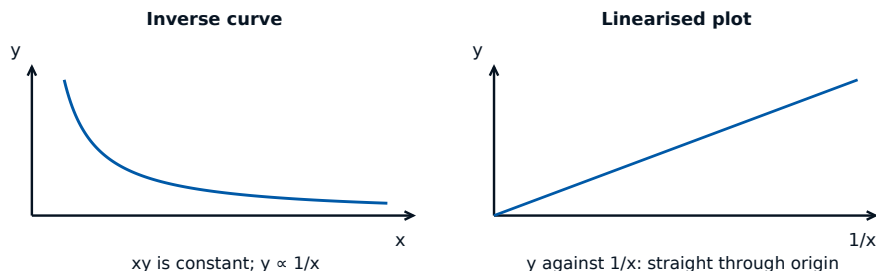
(F) (H) (T)

$y \propto x$ gives a straight line through the origin; y/x is constant.

S00.25 Inverse proportion

(F) (H) (T)

$y \propto 1/x$ means xy is constant.



S00.26 Significant figures

(F) (H) (T)

Keep extra digits during working; round the final answer to precision supported by the data/question.

S00.27 Standard form

(F) (H) (T)

$a \times 10^n$, with $1 \leq a < 10$ and integer n .

S00.28 SI prefixes

(F) (H) (T)

kilo 10^3 ; centi 10^{-2} ; milli 10^{-3} ; micro 10^{-6} ; nano 10^{-9} .

S00.29 Area and volume units

(F) (H) (T)

Square/cube the length conversion: $1 \text{ cm}^2 = 10^{-4} \text{ m}^2$; $1 \text{ cm}^3 = 10^{-6} \text{ m}^3$.

S00.30 Formula triangles

(F) (H) (T)

Cover the unknown to see a rearrangement for a three-variable product. Always check units and the equation's conditions.

Practical methods and calculations

S00.R01

(F) (H) (T)

CIDER(S): plan a method

C: control variables — what stays the same and how?

I: independent variable — what will you change?

D: dependent variable — what will you measure and how?

E: equipment — name suitable apparatus.

R: repeats, risks, range — repeat readings; choose a useful range.

S: safety and hazards — identify hazards and precautions.

Use these checks to write clear, ordered steps specific to the investigation.

S00.R02

(F) (H) (T)

FIFA: calculation steps

F: formula — write the correct equation.

I: insert values — include any needed unit conversions.

F: fine tune — rearrange to find the unknown.

A: answer with units — calculate, then round sensibly.

Example: $V = IR$; $12 = I \times 4$; $I = 12 \div 4 = 3 \text{ A}$.

Acronyms and reminders

Read the Full Meaning; Use the Acronym to Retrieve It Accurately

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PANIC

(F) (H) (T)

Positive Anode; Negative Is Cathode

P = Positive, A = Anode, N = Negative, I = Is, C = Cathode. In electrolysis, positive ions move to the negative cathode; negative ions move to the positive anode.

Use with C04.27

OIL RIG

(H) (T)

Oxidation Is Loss; Reduction Is Gain

The loss or gain is of electrons. Oxidation puts electrons on the right of a half equation; reduction has electrons on the left.

Use with C04.09

MRS GREN

(F) (H) (T)

Seven life processes

Movement, Respiration, Sensitivity, Growth, Reproduction, Excretion, Nutrition. Respiration releases energy through reactions; it is not simply breathing.

Use with B01

DRY MIX

(F) (H) (T)

Graph variables

Dependent, Responding, Y-axis; Manipulated, Independent, X-axis. The independent variable is changed; the dependent variable is measured.

Use with S00.06

LHS / RHS

(F) (H) (T)

Equation sides

Left-hand side / right-hand side. Balance atoms and total charge on both sides; never change correct subscripts just to balance an equation.

Use with C03.02

DC / AC

(F) (H) (T)

Electrical current

Direct current flows in one direction. Alternating current repeatedly reverses direction. UK mains is AC.

Use with P02

IV / DV / CV

(F) (H) (T)

Practical variables

Independent variable: change. Dependent variable: measure. Control variables: keep constant to make a valid comparison.

Use with S00.06

EM

(F) (H) (T)

Electromagnetic spectrum

Radio → microwave → infrared → visible → ultraviolet → X-ray → gamma. Frequency increases and wavelength decreases in this order.

Use with P06

CIDER(S)

(F) (H) (T)

Plan a practical method

C: control variables; I: independent variable; D: dependent variable; E: equipment; R: repeats, risks, range; S: safety and hazards. Write clear, ordered steps.

Use with S00.R01

FIFA

(F) (H) (T)

Calculation routine

F: formula; I: insert values; F: fine tune (rearrange); A: answer with units. Convert units where needed and show your working.

Use with S00.R02

Combined Foundation | Biology / chemistry / maths formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

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Magnification magnification = image size / real size Same units for both lengths; ratio has no unit.	(F) (H) (T)	Chromatography Rf Rf = distance moved by substance / solvent-front distance Both measured from baseline; ratio has no unit.	(F) (H) (T)
Percentage change $100 \times (\text{final} - \text{initial}) / \text{initial}$ Keep the sign; positive is an increase.	(F) (H) (T)	Mean mean = sum of readings / number of readings Explain any excluded anomalous reading.	(F) (H) (T)
Relative rate relative rate = $1 / \text{time}$ s^{-1} when time is in s; same fixed endpoint.	(F) (H) (T)	Gradient gradient = change in y / change in x Gradient units = y units / x units.	(F) (H) (T)
Population estimate mean per quadrat $\times$ total area / quadrat area Use representative, randomly placed quadrats.	(F) (H) (T)	Uncertainty from repeats uncertainty = (maximum – minimum) / 2 State as $\pm$ half the range where appropriate.	(F) (H) (T)
Neutrons neutrons = mass number – atomic number $A - Z$; a neutral atom has Z electrons.	(F) (H) (T)	Surface area : volume SA:V = surface area / volume; cube = $6/a$ Cube of side a: area $6a^2$, volume a^3 .	(F) (H) (T)
Relative atomic mass $A_r = \Sigma(\text{isotope mass} \times \text{abundance}) / \Sigma \text{abundances}$ For % abundances the denominator is 100. No unit.	(F) (H) (T)	Geometry rectangle area = lw; triangle area = $\frac{1}{2}bh$ circle area = πr^2 ; cuboid volume = lwh.	(F) (H) (T)
Relative formula mass M_r = sum of A_r values in the formula Include every atom and bracket multiplier; no unit.	(F) (H) (T)	Length and volume 1 mm = 1000 μm ; 1 μm = 1000 nm 1 dm^3 = 1000 cm^3 ; 1 cm^3 = 1 mL.	(F) (H) (T)
Mass percentage % element = total A_r for that element / $M_r \times 100$ Use all atoms of the element in one formula unit.	(F) (H) (T)	SI area / volume 1 cm^2 = 10^{-4} m^2 ; 1 cm^3 = 10^{-6} m^3 Square or cube the length conversion.	(F) (H) (T)
Mass concentration concentration = solute mass / solution volume g/dm^3 from g and dm^3 .	(F) (H) (T)	Direct / inverse proportion direct: $y = kx$; inverse: $y = k/x$ k is a constant; direct line goes through origin.	(F) (H) (T)
Mean reaction rate quantity of reactant used (or product made) / time For example g/s or cm^3/s .	(F) (H) (T)	Motion graph gradients speed = gradient of distance-time graph Acceleration = gradient of velocity-time graph.	(F) (H) (T)

Combined Foundation | Physics formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

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Kinetic energy (F)(H)(T) $E_k = \frac{1}{2}mv^2$ E_k J; m kg; v m/s.	Energy transferred (F)(H)(T) $E = Pt = QV$ E J; P W; t s; Q C; V volts.	Acceleration (F)(H)(T) $a = (v - u)/t$ a m/s ² ; v, u m/s; t s.
Elastic energy (F)(H)(T) $E_e = \frac{1}{2}ke^2$ J ; k N/m; e m; proportional region.	Series circuits (F)(H)(T) $R_{total} = R_1 + R_2 + \dots$; $V_{total} = V_1 + V_2 + \dots$ Current is the same throughout the circuit.	Uniform acceleration (F)(H)(T) $v^2 - u^2 = 2as$ Constant a m/s ² ; v, u m/s; s m.
Gravitational energy (F)(H)(T) $E_p = mgh$ J ; m kg; g N/kg; height change h m.	Parallel circuits (F)(H)(T) $I_{total} = I_1 + I_2 + \dots$ Potential difference is equal across branches.	Resultant force (F)(H)(T) $F = ma$ F N; m kg; a m/s ² . Use the resultant force.
Thermal energy change (F)(H)(T) $\Delta E = mc\Delta\theta$ J ; m kg; c J/(kg °C); $\Delta\theta$ °C.	Density (F)(H)(T) $\rho = m/V$ kg/m^3 from kg and m^3 ; or g/cm^3 .	Wave period (F)(H)(T) $T = 1/f$ Period T s; frequency f Hz.
Power (F)(H)(T) $P = E/t = W/t$ P W; energy E or work W J; t s.	Latent heat (F)(H)(T) $E = mL$ E J; m kg; L J/kg; temperature stays fixed.	Wave speed (F)(H)(T) $v = f\lambda$ v m/s; f Hz; wavelength λ m.
Efficiency (F)(H)(T) useful energy output / total energy input Or useful power / total power; $\times 100$ for %.	Weight (F)(H)(T) $W = mg$ Weight W N; mass m kg; g N/kg.	Stopping distance (F)(H)(T) stopping = thinking + braking distance All distances in metres.
Charge flow (F)(H)(T) $Q = It$ Q C; I A; t s.	Work done (F)(H)(T) $W = Fs$ W J; F N; s m along the force direction.	Corrected count rate (F)(H)(T) source count rate = measured rate – background rate Same time units and detector conditions.
Potential difference (F)(H)(T) $V = IR$ V volts; I amperes; R ohms (Ω).	Spring force (F)(H)(T) $F = ke$ F N; k N/m; extension e m; proportional region.	Frequency measurement (F)(H)(T) f = number of oscillations / time f Hz; time s . Measure several cycles.
Electrical power (F)(H)(T) $P = VI = I^2R$ P W; V volts; I amperes; R Ω .	Speed / distance (F)(H)(T) $v = s/t$; $s = vt$ v m/s; distance s m; t s; mean speed for journey.	

Combined Higher | Biology / chemistry / maths formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

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Magnification (F)(H)(T) magnification = image size / real size Same units for both lengths; ratio has no unit.	Moles and mass (H)(T) $n = \text{mass} / M_r$; $\text{mass} = n \times M_r$ n in mol; mass in g; use A_r for single atoms.	Surface area : volume (F)(H)(T) $SA:V = \text{surface area} / \text{volume}$; cube = $6/a$ Cube of side a: area $6a^2$, volume a^3 .
Percentage change (F)(H)(T) $100 \times (\text{final} - \text{initial}) / \text{initial}$ Keep the sign; positive is an increase.	Particle number (H)(T) $N = n \times N_a$ $N_a = 6.02 \times 10^{23} \text{ mol}^{-1}$; n in mol.	Geometry (F)(H)(T) rectangle area = lw; triangle area = $\frac{1}{2}bh$ circle area = πr^2 ; cuboid volume = lwh.
Relative rate (F)(H)(T) relative rate = 1 / time s^{-1} when time is in s; same fixed endpoint.	Reacting mole ratio (H)(T) $n(\text{required}) = n(\text{known}) \times \text{coefficient ratio}$ Required coefficient / known coefficient.	Length and volume (F)(H)(T) 1 mm = 1000 μm ; 1 μm = 1000 nm 1 dm^3 = 1000 cm^3 ; 1 cm^3 = 1 mL.
Population estimate (F)(H)(T) mean per quadrat $\times$ total area / quadrat area Use representative, randomly placed quadrats.	Mean reaction rate (F)(H)(T) quantity of reactant used (or product made) / time For example g/s or cm^3/s .	SI area / volume (F)(H)(T) 1 $\text{cm}^2 = 10^{-4} \text{ m}^2$; 1 $\text{cm}^3 = 10^{-6} \text{ m}^3$ Square or cube the length conversion.
Neutrons (F)(H)(T) neutrons = mass number – atomic number $A - Z$; a neutral atom has Z electrons.	Energy from bonds (H)(T) $\Delta H = \Sigma(\text{bond energies broken}) - \Sigma(\text{bond energies made})$ kJ/mol; positive endothermic, negative exothermic.	Light intensity (H)(T) $I \propto 1/d^2$; $I_1/I_2 = d_2^2/d_1^2$ Point source; compare the same source and conditions.
Relative atomic mass (F)(H)(T) $A_r = \Sigma(\text{isotope mass} \times \text{abundance}) / \Sigma \text{abundances}$ For % abundances the denominator is 100. No unit.	Chromatography R_f (F)(H)(T) $R_f = \text{distance moved by substance} / \text{solvent-front distance}$ Both measured from baseline; ratio has no unit.	Instantaneous reaction rate (H)(T) rate = gradient of tangent to quantity-time curve Use a large triangle on the tangent; appropriate units.
Relative formula mass (F)(H)(T) $M_r = \text{sum of } A_r \text{ values in the formula}$ Include every atom and bracket multiplier; no unit.	Mean (F)(H)(T) mean = sum of readings / number of readings Explain any excluded anomalous reading.	Rate using moles (H)(T) rate = amount changed / time mol/s when amount is mol and time is s.
Mass percentage (F)(H)(T) % element = total A_r for that element / $M_r \times 100$ Use all atoms of the element in one formula unit.	Gradient (F)(H)(T) gradient = change in y / change in x Gradient units = y units / x units.	Direct / inverse proportion (F)(H)(T) direct: $y = kx$; inverse: $y = k/x$ k is a constant; direct line goes through origin.
Mass concentration (F)(H)(T) concentration = solute mass / solution volume g/dm^3 from g and dm^3 .	Uncertainty from repeats (F)(H)(T) uncertainty = (maximum – minimum) / 2 State as $\pm$ half the range where appropriate.	Motion graph gradients (F)(H)(T) speed = gradient of distance-time graph Acceleration = gradient of velocity-time graph.

Combined Higher | Physics formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

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Kinetic energy $E_k = \frac{1}{2}mv^2$ E_k J; m kg; v m/s.	(F)(H)(T)	Parallel circuits $I_{total} = I_1 + I_2 + \dots$ Potential difference is equal across branches.	(F)(H)(T)	Momentum conservation $\Sigma \text{momentum before} = \Sigma \text{momentum after}$ Closed system; no external resultant force.	(H)(T)
Elastic energy $E_e = \frac{1}{2}ke^2$ J ; k N/m; e m; proportional region.	(F)(H)(T)	Density $\rho = m/V$ kg/m^3 from kg and m^3 ; or g/cm^3 .	(F)(H)(T)	Wave period $T = 1/f$ Period T s; frequency f Hz.	(F)(H)(T)
Gravitational energy $E_p = mgh$ J ; m kg; g N/kg; height change h m.	(F)(H)(T)	Latent heat $E = mL$ E J; m kg; L J/kg; temperature stays fixed.	(F)(H)(T)	Wave speed $v = f\lambda$ v m/s; f Hz; wavelength λ m.	(F)(H)(T)
Thermal energy change $\Delta E = mc\Delta\theta$ J ; m kg; c J/(kg °C); $\Delta\theta$ °C.	(F)(H)(T)	Weight $W = mg$ Weight W N; mass m kg; g N/kg.	(F)(H)(T)	Motor force $F = BIl$ F N; B T; I A; l m. Wire perpendicular to field.	(H)(T)
Power $P = E/t = W/t$ P W; energy E or work W J; t s.	(F)(H)(T)	Work done $W = Fs$ W J; F N; s m along the force direction.	(F)(H)(T)	Ideal transformer power $V_p I_p = V_s I_s$ V volts; I A; 100% efficient transformer.	(H)(T)
Efficiency useful energy output / total energy input Or useful power / total power; $\times 100$ for %.	(F)(H)(T)	Spring force $F = ke$ F N; k N/m; extension e m; proportional region.	(F)(H)(T)	Half-life calculations remaining fraction = $(\frac{1}{2})^n$; n = time / half-life Use matching time units. Subtract background.	(H)(T)
Charge flow $Q = It$ Q C; I A; t s.	(F)(H)(T)	Speed / distance $v = s/t$; $s = vt$ v m/s; distance s m; t s; mean speed for journey.	(F)(H)(T)	Stopping distance stopping = thinking + braking distance All distances in metres.	(F)(H)(T)
Potential difference $V = IR$ V volts; I amperes; R ohms (Ω).	(F)(H)(T)	Acceleration $a = (v - u)/t$ a m/s ² ; v, u m/s; t s.	(F)(H)(T)	Corrected count rate source count rate = measured rate – background rate Same time units and detector conditions.	(F)(H)(T)
Electrical power $P = VI = I^2R$ P W; V volts; I amperes; R Ω .	(F)(H)(T)	Uniform acceleration $v^2 - u^2 = 2as$ Constant a m/s ² ; v, u m/s; s m.	(F)(H)(T)	Area under a motion graph displacement = signed area under velocity-time graph Distance = area under a speed-time graph.	(H)(T)
Energy transferred $E = Pt = QV$ E J; P W; t s; Q C; V volts.	(F)(H)(T)	Resultant force $F = ma$ F N; m kg; a m/s ² . Use the resultant force.	(F)(H)(T)	Frequency measurement f = number of oscillations / time f Hz; time s . Measure several cycles.	(F)(H)(T)
Series circuits $R_{total} = R_1 + R_2 + \dots$; $V_{total} = V_1 + V_2 + \dots$ Current is the same throughout the circuit.	(F)(H)(T)	Momentum $p = mv$ p kg m/s; m kg; v m/s. Include direction.	(H)(T)		

Triple Higher | Biology / chemistry / maths formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

MY RETRIEVAL PRACTICE

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Magnification (F) (H) (T) magnification = image size / real size Same units for both lengths; ratio has no unit.	Particle number (H) (T) $N = n \times N_a$ $N_a = 6.02 \times 10^{23} \text{ mol}^{-1}$; n in mol.	Gradient (F) (H) (T) gradient = change in y / change in x Gradient units = y units / x units.
Percentage change (F) (H) (T) $100 \times (\text{final} - \text{initial}) / \text{initial}$ Keep the sign; positive is an increase.	Reacting mole ratio (H) (T) $n(\text{required}) = n(\text{known}) \times \text{coefficient ratio}$ Required coefficient / known coefficient.	Uncertainty from repeats (F) (H) (T) uncertainty = (maximum – minimum) / 2 State as $\pm$ half the range where appropriate.
Relative rate (F) (H) (T) relative rate = 1 / time s^{-1} when time is in s; same fixed endpoint.	Molar concentration (T) $c = n/V$; $n = cV$ c in mol/dm^3 ; V in dm^3 ; n in mol.	Surface area : volume (F) (H) (T) SA:V = surface area / volume; cube = $6/a$ Cube of side a: area $6a^2$, volume a^3 .
Population estimate (F) (H) (T) mean per quadrat $\times$ total area / quadrat area Use representative, randomly placed quadrats.	Concentration conversion (T) $\text{g/dm}^3 = \text{mol/dm}^3 \times \text{molar mass}$ Molar mass in g/mol ; same numeric value as M_r .	Geometry (F) (H) (T) rectangle area = lw; triangle area = $\frac{1}{2}bh$ circle area = πr^2 ; cuboid volume = lwh.
Bacterial growth (T) $N = N_0 \times 2^n$; n = elapsed time / division time Constant favourable conditions; n = divisions.	Titration amounts (T) $c_1V_1 / \text{coefficient}_1 = c_2V_2 / \text{coefficient}_2$ c in mol/dm^3 , V in dm^3 . Balance first.	Length and volume (F) (H) (T) 1 mm = 1000 μm ; 1 μm = 1000 nm 1 dm^3 = 1000 cm^3 ; 1 cm^3 = 1 mL.
Biomass transfer (T) efficiency (%) = biomass transferred / biomass available $\times$ 100 Use equivalent mass units and trophic levels.	Gas volume at RTP (T) $V = 24n$; $n = V/24$ V in dm^3 ; n in mol; 20°C and 1 atmosphere.	SI area / volume (F) (H) (T) 1 $\text{cm}^2 = 10^{-4} \text{ m}^2$; 1 $\text{cm}^3 = 10^{-6} \text{ m}^3$ Square or cube the length conversion.
Neutrons (F) (H) (T) neutrons = mass number – atomic number A – Z; a neutral atom has Z electrons.	Percentage yield (T) actual yield / theoretical yield $\times$ 100 Compare masses in the same units.	Light intensity (H) (T) $I \propto 1/d^2$; $I_1/I_2 = d_2^2/d_1^2$ Point source; compare the same source and conditions.
Relative atomic mass (F) (H) (T) $A_r = \Sigma(\text{isotope mass} \times \text{abundance}) / \Sigma \text{abundances}$ For % abundances the denominator is 100. No unit.	Atom economy (T) $M_r \text{ of desired products} / M_r \text{ of all reactants} \times 100$ Include balanced-equation coefficients.	Instantaneous reaction rate (H) (T) rate = gradient of tangent to quantity-time curve Use a large triangle on the tangent; appropriate units.
Relative formula mass (F) (H) (T) M_r = sum of A_r values in the formula Include every atom and bracket multiplier; no unit.	Mean reaction rate (F) (H) (T) quantity of reactant used (or product made) / time For example g/s or cm^3/s .	Rate using moles (H) (T) rate = amount changed / time mol/s when amount is mol and time is s.
Mass percentage (F) (H) (T) % element = total A_r for that element / $M_r \times 100$ Use all atoms of the element in one formula unit.	Energy from bonds (H) (T) $\Delta H = \Sigma(\text{bond energies broken}) - \Sigma(\text{bond energies made})$ kJ/mol ; positive endothermic, negative exothermic.	Titration volume (T) titre = final burette reading – initial reading cm^3 ; average concordant titres after a rough run.
Mass concentration (F) (H) (T) concentration = solute mass / solution volume g/dm^3 from g and dm^3 .	Chromatography R_f (F) (H) (T) R_f = distance moved by substance / solvent-front distance Both measured from baseline; ratio has no unit.	Direct / inverse proportion (F) (H) (T) direct: $y = kx$; inverse: $y = k/x$ k is a constant; direct line goes through origin.
Moles and mass (H) (T) $n = \text{mass} / M_r$; $\text{mass} = n \times M_r$ n in mol; mass in g; use A_r for single atoms.	Mean (F) (H) (T) mean = sum of readings / number of readings Explain any excluded anomalous reading.	Motion graph gradients (F) (H) (T) speed = gradient of distance-time graph Acceleration = gradient of velocity-time graph.

Triple Higher | Physics formulae

Use and Rearrange These Relationships; Check Quantities, Units and Conditions

MY RETRIEVAL PRACTICE

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Kinetic energy (F) (H) (T) $E_k = \frac{1}{2}mv^2$ E_k J; m kg; v m/s.	Gas pressure and volume (T) $p_1V_1 = p_2V_2$ Fixed gas mass and temperature; matching units.	Force and momentum (T) $F = \Delta p / \Delta t = m \Delta v / \Delta t$ F N; Δp kg m/s; Δt s; constant mass.
Elastic energy (F) (H) (T) $E_e = \frac{1}{2}ke^2$ J ; k N/m; e m; proportional region.	Weight (F) (H) (T) $W = mg$ Weight W N; mass m kg; g N/kg.	Wave period (F) (H) (T) $T = 1/f$ Period T s; frequency f Hz.
Gravitational energy (F) (H) (T) $E_p = mgh$ J ; m kg; g N/kg; height change h m.	Work done (F) (H) (T) $W = Fs$ W J; F N; s m along the force direction.	Wave speed (F) (H) (T) $v = f\lambda$ v m/s; f Hz; wavelength λ m.
Thermal energy change (F) (H) (T) $\Delta E = mc\Delta\theta$ J ; m kg; c J/(kg °C); $\Delta\theta$ °C.	Spring force (F) (H) (T) $F = ke$ F N; k N/m; extension e m; proportional region.	Echo distance (T) distance to reflector = $vt/2$ v m/s; round-trip time t s.
Power (F) (H) (T) $P = E/t = W/t$ P W; energy E or work W J; t s.	Moment (T) $M = Fd$ M N m; F N; perpendicular distance d m.	Lens magnification (T) magnification = image height / object height Same units; ratio has no unit.
Efficiency (F) (H) (T) useful energy output / total energy input Or useful power / total power; $\times 100$ for %.	Balanced moments (T) $\Sigma \text{clockwise moments} = \Sigma \text{anticlockwise moments}$ About the same pivot, in equilibrium.	Motor force (H) (T) $F = BIl$ F N; B T; I A; l m. Wire perpendicular to field.
Charge flow (F) (H) (T) $Q = It$ Q C; I A; t s.	Pressure on a surface (T) $p = F/A$ p Pa; normal force F N; A m ² .	Transformer turns (T) $V_p/V_s = n_p/n_s$ V volts; n turns; p primary, s secondary.
Potential difference (F) (H) (T) $V = IR$ V volts; I amperes; R ohms (Ω).	Liquid pressure (T) $p = h\rho g$ p Pa due to liquid; h m; ρ kg/m ³ ; g N/kg.	Ideal transformer power (H) (T) $V_p I_p = V_s I_s$ V volts; I A; 100% efficient transformer.
Electrical power (F) (H) (T) $P = VI = I^2R$ P W; V volts; I amperes; R Ω .	Speed / distance (F) (H) (T) $v = s/t$; $s = vt$ v m/s; distance s m; t s; mean speed for journey.	Half-life calculations (H) (T) remaining fraction = $(\frac{1}{2})^n$; n = time / half-life Use matching time units. Subtract background.
Energy transferred (F) (H) (T) $E = Pt = QV$ E J; P W; t s; Q C; V volts.	Acceleration (F) (H) (T) $a = (v - u)/t$ a m/s ² ; v, u m/s; t s.	Stopping distance (F) (H) (T) stopping = thinking + braking distance All distances in metres.
Series circuits (F) (H) (T) $R_{\text{total}} = R_1 + R_2 + \dots$; $V_{\text{total}} = V_1 + V_2 + \dots$ Current is the same throughout the circuit.	Uniform acceleration (F) (H) (T) $v^2 - u^2 = 2as$ Constant a m/s ² ; v, u m/s; s m.	Corrected count rate (F) (H) (T) source count rate = measured rate – background rate Same time units and detector conditions.
Parallel circuits (F) (H) (T) $I_{\text{total}} = I_1 + I_2 + \dots$ Potential difference is equal across branches.	Resultant force (F) (H) (T) $F = ma$ F N; m kg; a m/s ² . Use the resultant force.	Area under a motion graph (H) (T) displacement = signed area under velocity-time graph Distance = area under a speed-time graph.
Density (F) (H) (T) $\rho = m/V$ kg/m ³ from kg and m ³ ; or g/cm ³ .	Momentum (H) (T) $p = mv$ p kg m/s; m kg; v m/s. Include direction.	Frequency measurement (F) (H) (T) f = number of oscillations / time f Hz; time s . Measure several cycles.
Latent heat (F) (H) (T) $E = mL$ E J; m kg; L J/kg; temperature stays fixed.	Momentum conservation (H) (T) $\Sigma \text{momentum before} = \Sigma \text{momentum after}$ Closed system; no external resultant force.	

Periodic table | AQA GCSE reference

All Courses | Use the AQA Relative Atomic Masses for Calculations

MY RETRIEVAL PRACTICE

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The Periodic Table of Elements

1	2											3	4	5	6	7	0	
																		4 He helium 2
</																		

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

Insert for GCSE Chemistry (8462), Combined Science: Trilogy (8464), and Combined Science: Synergy (8465) papers v1

Required practical cross-reference

Com = Combined Science; Bio / Chem / Phys = Separate Qualification

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Microscopy Com 01 Bio 01 B01	(F)(H)(T)	Reaction rate Com 11 Chem 05 C06	(F)(H)(T)
Culturing microorganisms Com - Bio 02 B01	(T)	Chromatography Com 12 Chem 06 C08	(F)(H)(T)
Osmosis Com 02 Bio 03 B01	(F)(H)(T)	Identifying ions Com - Chem 07 C08	(T)
Food Testing Com 03 Bio 04 B02	(F)(H)(T)	Water purification Com 13 Chem 08 C10	(F)(H)(T)
Amylase and pH Com 04 Bio 05 B02	(F)(H)(T)	Specific heat capacity Com 14 Phys 01 P01	(F)(H)(T)
Photosynthesis and light Com 05 Bio 06 B04	(F)(H)(T)	Thermal insulation Com - Phys 02 P01	(T)
Reaction time Com 06 Bio 07 B05	(F)(H)(T)	Resistance Com 15 Phys 03 P02	(F)(H)(T)
Plant responses Com - Bio 08 B05	(T)	I-V characteristics Com 16 Phys 04 P02	(F)(H)(T)
Field investigation Com 07 Bio 09 B07	(F)(H)(T)	Density / displacement Com 17 Phys 05 P03	(F)(H)(T)
Lipase Method / decay Com - Bio 10 B07	(T)	Force and extension Com 18 Phys 06 P05	(F)(H)(T)
Soluble salt preparation Com 08 Chem 01 C04	(F)(H)(T)	Force and acceleration Com 19 Phys 07 P05	(F)(H)(T)
Titration Com - Chem 02 C04	(T)	Waves Com 20 Phys 08 P06	(F)(H)(T)
Electrolysis Com 09 Chem 03 C04	(F)(H)(T)	Light: reflection/refraction Com - Phys 09 P06	(T)
Temperature changes Com 10 Chem 04 C05	(F)(H)(T)	Infrared radiation Com 21 Phys 10 P06	(F)(H)(T)

These are recall notes for practical work. Follow the teacher's instructions, risk assessment and disposal arrangements. A practical may assess the method, apparatus, variables, uncertainty, results and explanation.

Sources, scope and study notes

AQA GCSE Science Specifications and Reference Materials

MY RETRIEVAL PRACTICE

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Combined Science: Trilogy 8464

<https://www.aqa.org.uk/subjects/science/gcse/science-8464/specification>

Biology 8461

<https://www.aqa.org.uk/subjects/biology/gcse/biology-8461/specification>

Chemistry 8462

<https://www.aqa.org.uk/subjects/chemistry/gcse/chemistry-8462/specification>

Physics 8463

<https://www.aqa.org.uk/subjects/physics/gcse/physics-8463/specification>

AQA GCSE periodic table

<https://filestore.aqa.org.uk/resources/science/AQA-8462-8464-8465-INS-PT.PDF>

AQA biology practical method: lipase / milk

<https://filestore.aqa.org.uk/resources/biology/AQA-8461-PRACTICALS.PDF>

AQA 2027 equation-sheet guidance

<https://www.aqa.org.uk/news/gcse-maths-sciences-formulae-equation-sheets-2027-28>

AQA Physics 2027 equations

<https://www.aqa.org.uk/filestore/physics/AQA-GCSE-Science-8463-INS-AI-V2.3.pdf>

Course icons show which qualification each item belongs to. F = Combined Foundation; H = Combined Higher; T = Separate Science Higher. This booklet does not cover Separate Science Foundation as a separate programme.

The 2027 physics equation inserts are provided in examinations. These summaries support choosing, rearranging and using formulae, not just memorising symbols. Biology and chemistry calculation relationships also need practice.

M_r means relative formula mass (relative molecular mass for molecules); A_r means relative atomic mass. Neither has a unit. Their numerical values match molar mass expressed in g/mol.

Use alongside experiments and examination practice; the specification remains authoritative.

The thinking behind the guidance.

Research informing the study routines in this book. Follow the links to explore the original work.

1 Cowan (2014)

Working memory, learning and education.
<https://pubmed.ncbi.nlm.nih.gov/25346585/>

2 Dunlosky et al. (2013)

Improving Students' Learning With Effective Learning Techniques.
<https://doi.org/10.1177/1529100612453266>

3 Roediger & Karpicke (2006)

Retrieval practice and longer-term retention.
<https://doi.org/10.1111/j.1467-9280.2006.01693.x>

4 Agarwal, Bain & Chamberlain (2012)

Retrieval practice in school classrooms.
<https://doi.org/10.1007/s10648-012-9210-2>

5 Cepeda et al. (2008)

Spacing, review intervals and retention.
<https://doi.org/10.1111/j.1467-9280.2008.02209.x>

6 Karpicke & Roediger (2007)

Repeated retrieval and long-term retention.
<https://doi.org/10.1016/j.jml.2006.09.004>

7 Bjork Learning & Forgetting Lab

Desirable difficulties: useful, manageable challenges.
<https://bjorklab.psych.ucla.edu/research/>

8 Rohrer et al. (2020)

Randomised classroom study of interleaved maths practice.
<https://doi.org/10.1037/edu0000367>

9 Pan & Rickard (2018)

Transfer of test-enhanced learning: meta-analytic review.
<https://doi.org/10.1037/bul0000151>

10 Rohrer & Taylor (2007)

The shuffling of mathematics problems improves learning.
<https://doi.org/10.1007/s11251-007-9015-8>

11 Emeny, W. G., Hartwig, M. K., & Rohrer, D. (2021)

Spaced mathematics practice improves test scores and reduces overconfidence.
Applied Cognitive Psychology, 35(4), 1082–1089.
<https://doi.org/10.1002/acp.3814>

Judge learning by what you can recall later.

Use retrieval and spaced returns, then apply your knowledge. Your RAG judgement should follow an honest attempt, not just familiarity with the page.

A little today. Stronger tomorrow.

1

Choose

A few items carrying your course letter.

2

Retrieve

Cover the answer. Say it, write it or draw it.

3

Check

Find what is accurate and correct the gaps.

4

Return

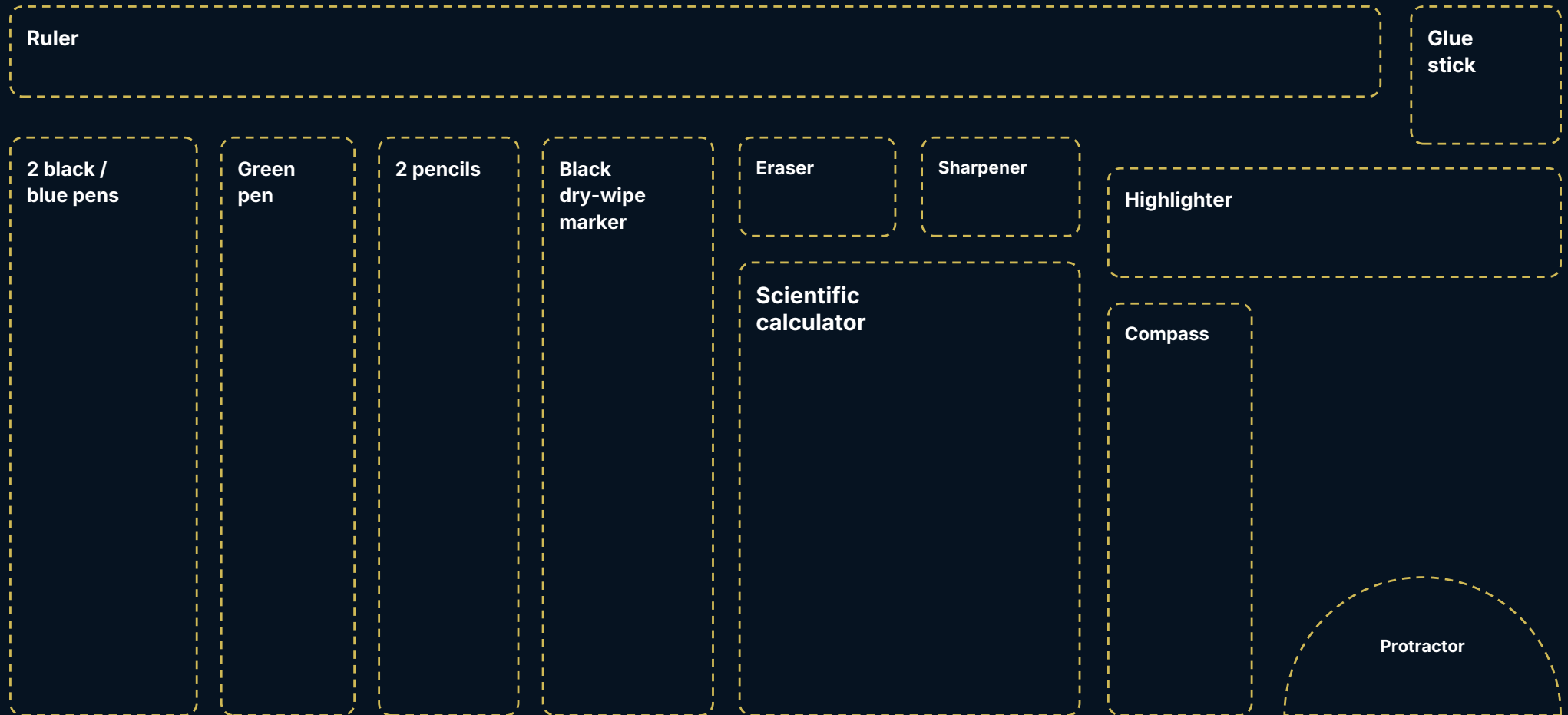
Set a date to try again after a delay.

THINK deeply. GROW in confidence. CARE for each other.

Ready to learn.

PACK. CHECK. GO.

Lay out your equipment and check the spaces before you pack your bag.



Also pack: your timetable in its wallet, this organiser, and the exercise books or folders for your lessons.

Equipment check spaces are not drawn to scale. Follow your teacher's instructions for practical work.