Ecolint
Campus des Nations

Year 9 Science

Unit 1

Atomic Structure, the Periodic Table & Chemical Change

Statement of inquiry — simple models allow us to explain patterns and make predictions about chemical change.

v2.1

STUDENT WORKBOOK

Name _____

Class _____

Teacher _____

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How this book works — section icons

- **Do now** — retrieve from memory
- **Learn** — read & study this
- **Investigate** — simulation / practical
- **Did you know?** — fact, history, extension
- **Key words** — vocabulary to master
- **Practise** — your turn to write
- **Check** — test yourself

The printed book is black & white; the digital edition uses the Ecolint colours.

1.1 Modelling matter & classifying substances

Key words

Write what each word means, in your own words, as we meet it.

matter _____

particle model _____

elemental substance _____

compound substance _____

mixture _____

homogeneous mixture _____

heterogeneous mixture _____

Do now

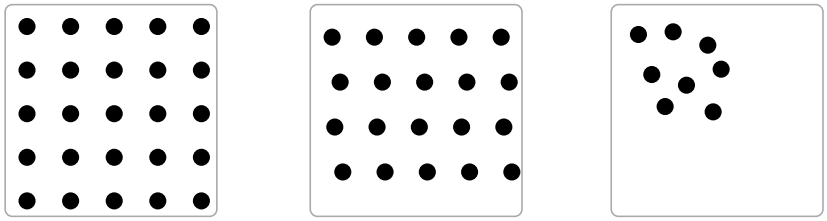
1. What are the three states of matter?

   _____

2. Draw a quick sketch of how the particles are arranged in a solid, a liquid and a gas.

What is matter, and how do we model it?

Matter is the 'stuff' around us. We can define matter as anything that has **mass** and **volume**. It is ultimately made up of atoms, which are composed of subatomic particles. To explain how matter behaves, scientists use the **particle model**: all matter is made of tiny, identical particles in constant motion, with forces of attraction between them. How much energy those particles have decides whether a substance is a **solid**, a **liquid** or a **gas**.



Solid — fixed, packed **Liquid** — close, can move **Gas** — far apart, fast

SCOPE — THE EDGE OF THE MODEL

At this level Matter comes in **three** states: solid, liquid and gas. Everything in this unit works with those three.

Beyond it There is a fourth state, **plasma**. Heat a gas far enough and electrons are stripped from the atoms, leaving a mixture of ions and free electrons. Stars, lightning and neon signs are plasma; by mass, most of the visible universe is in this state.

Not assessed. The three states are what you need.

Classifying substances

Substances can be classified according to their atomic structure — the number of atoms, and the type(s) of atom(s), in the particles that make them up.

Elemental substances are all made up of **the same type of atom**. They can be molecules made of two or more atoms joined together, as long as they are the same type of atom, e.g. O_2 and H_2.

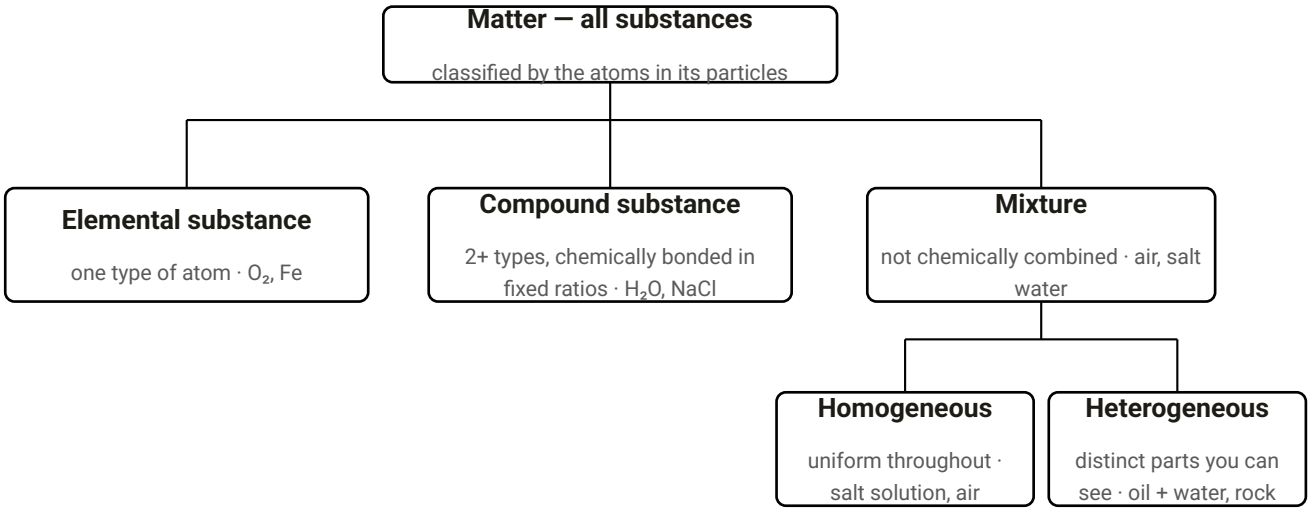
Compound substances are made up of **two or more types of atoms chemically combined in fixed ratios**, e.g. H_2O, $C_6H_{12}O_6$, NaCl. The ratio is **fixed** — water is always 2 hydrogen to 1 oxygen, never 3:1 — and that ratio is exactly what the formula shows.

Chemically combined means the atoms are joined by chemical bonds — they can only be separated by another chemical reaction, not by simply filtering or heating.

Mixtures involve different substances that are **mixed but not chemically combined**. They have no fixed ratios, e.g. air, salt water, vinegar.

Heterogeneous mixtures are in two or more distinct 'phases': you can easily see the separate parts of the mixture — such as oil and water or a rock.

Homogeneous mixtures are uniform in their composition — we can see one blended mix that looks the same throughout — such as a salt solution or air.



One way to classify any substance: is it one type of atom, more than one type chemically bonded, or just mixed?

DID YOU KNOW?

For 2000 years people thought everything was made from just four “elements” — earth, air, fire and water. We now know of about 118 real elements. **Models change as evidence improves** — the big idea of this whole unit.

DID YOU KNOW?

How pure is “pure”? In the USA, **NIST** (the National Institute of Standards and Technology) sells over a thousand **Standard Reference Materials** — samples whose exact make-up is certified. Labs check their instruments against these known mixtures, so a measurement in one lab means the same in another. It is classification and measurement taken to the limit.

Elemental substance, compound or mixture?

Sort each substance into the table.

iron · carbon dioxide · air · pure water · salt water · oxygen · sea water · sugar

Elemental substance	Compound substance	Mixture

Explain. Why is air classed as a mixture and not a compound?

Explain. Salt water contains both water molecules and sodium chloride. Is it a compound or a mixture? How do you know?

Check ✓

Circle the **one** best answer.

1. Which is a **compound**? A. O_2 B. air C. H_2O D. iron
2. In a **gas**, the particles are: A. packed in a fixed pattern B. close but moving C. far apart and fast D. not moving
3. A substance made of only one type of atom is a(n): A. mixture B. compound substance C. elemental substance D. solution

1.2 Symbols, formulae & representing substances

Key words

Write what each word means as we meet it.

chemical symbol _____

chemical formula _____

subscript _____

diatomic molecule _____

Do now

1. **(Last lesson)** What is the difference between an element and a compound?

   _____

2. Give one example of each.

   _____

Symbols and formulae

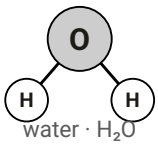
Every element has a **chemical symbol** — one or two letters, the **first always a capital** and the second (if any) **always lowercase**: C, He, Na, Fe. Compounds are written as a **chemical formula** using symbols and **subscripts** that show how many of each atom are present. A subscript applies to the symbol just before it; brackets group atoms, and the subscript outside multiplies everything inside.

WORKED EXAMPLE

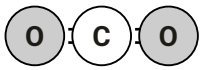
How many atoms of each element are in **$Ca(OH)_2$**?

The bracket (OH) is multiplied by 2 → 1 calcium, 2 oxygen, 2 hydrogen — **5 atoms in total**.

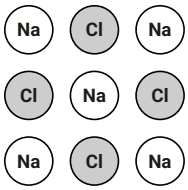
Read each formula straight off the picture



water · H_2O



carbon dioxide · CO_2



salt lattice · NaCl

A full Periodic Table is at the **back of this book** (appendix) — use it whenever you need an element's symbol.

SCOPE — THE EDGE OF THE MODEL

At this level One type of atom means one elemental substance: carbon is carbon, oxygen is oxygen.

Beyond it The same atoms can be arranged in different ways to give different substances, called **allotropes**. Carbon atoms alone give both **diamond** (hard, transparent) and **graphite** (soft, grey, the "lead" in a pencil). Oxygen atoms alone give both O_2 and O_3 (ozone), which have different properties.

Not assessed. Allotropes are a Year 10 topic. Here, both are still elemental substances.

Reading symbols & formulae

Fill in the missing names or symbols.

Symbol	Cu	N	S	Fe
Name				

Count the atoms of each element:

Formula	**Atoms**	**Formula**	**Atoms**
H_2O		H_2SO_4	
CO_2		$2\ CO_2$	
C_2H_6		$(NH_4)_2SO_4$	

DID YOU KNOW?

Some symbols look nothing like the English name: **Na** (sodium) comes from Latin **natrium**; **Fe** (iron) from **ferrum**; **Pb** (lead) from **plumbum** — the root of "plumber".

Check

1. Which is written correctly? A. NACL B. NaCl C. naCl D. Nacl
2. How many oxygen atoms in **2 H_2O**? A. 1 B. 2 C. 3 D. 4
3. How many atoms in total in **$CaCO_3$**? A. 3 B. 4 C. 5 D. 6

1.3 Inside the atom — the Bohr model

Key words

Write what each word means as we meet it.

nucleus _____

proton _____

neutron _____

electron _____

shell (energy level) _____

Do now

1. Name one element and one compound.

   _____

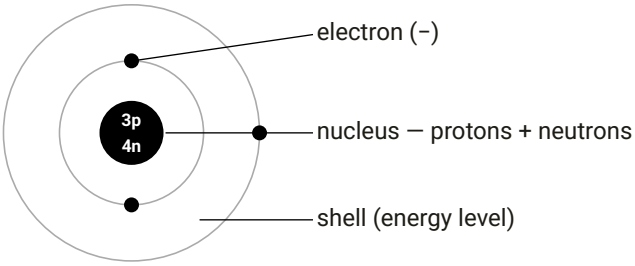
2. Atoms are far too small to see. So how do you think scientists worked out what is inside them?

   _____

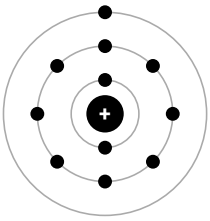
What is inside an atom?

An atom has a tiny central **nucleus** containing **protons** and **neutrons**. **Electrons** move around the nucleus in **shells** — also called energy levels. Almost all the mass is in the nucleus; almost all the volume is empty space where the electrons move. The three subatomic particles have the following properties:

Particle	Relative charge	Relative mass	Where found
Proton	+1	1	in the nucleus
Neutron	0	1	in the nucleus
Electron	−1	≈ 0 (about 1/1836)	in shells around the nucleus



the parts of an atom (lithium-7 shown)



the Bohr model

The Bohr model pictures electrons orbiting the nucleus in fixed shells, like planets around the Sun. It is a **model** — not a photograph — but it explains a huge amount, which is why we still use it.

Shells fill from the inside out: **2, then 8, then 8** (for the first 20 elements).

But the Bohr model isn't the whole story. Electrons don't really travel in neat circles — they exist in fuzzy regions called **orbitals** (the modern "quantum" model). The Bohr model also struggles to explain heavier elements and the details of bonding and light. We keep it because it is **simple and predicts well** — a perfect example of **"all models are wrong, but some are useful."**

PhET: Build an Atom — practise what you have learned

Now that you know the three subatomic particles, use the simulation to **check your understanding**. Build atoms by dragging protons, neutrons and electrons into place. Use the Element, Net Charge and Mass Number displays to verify your answers to the table below.

phet.colorado.edu/en/simulations/build-an-atom · **live in the digital edition**

DID YOU KNOW? — THE ATOM'S STORY

Our picture of the atom **changed four times** in 100 years: Dalton's solid sphere (1803) → Thomson's "plum pudding" (1897) → Rutherford's nucleus (1911) → Bohr's shells (1913). Each new experiment overturned the last model — exactly what this unit's statement of inquiry is about.

Dalton 1803

atoms are tiny **solid spheres** — like billiard balls.

Thomson 1897

a positive "pudding" with **electrons** dotted through it.

Rutherford 1911

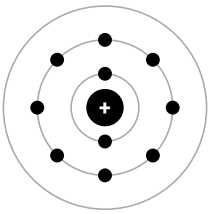
a tiny dense **nucleus**; the atom is mostly **empty space**.

Bohr 1913

electrons orbit the nucleus in fixed **shells**.

Label & build

Label this atom with: nucleus, proton, neutron, electron, shell.



Use the rules to complete the table.

Atom	Protons	Neutrons	Electrons
Helium (2 protons, 2 neutrons)			
Carbon (6 protons, 6 neutrons)			
Sodium (11 protons, 12 neutrons)			

Check

1. The nucleus contains: A. protons only B. protons & electrons C. protons & neutrons D. electrons only
2. Most of an atom's **mass** is in the: A. shells B. nucleus C. electrons D. empty space
3. The Bohr model is best described as: A. a photograph B. a useful model C. proven fact D. a guess

1.4 Atomic notation & electron arrangements

Key words

Write what each word means, in your own words, as we meet it.

atomic number (Z) _____

mass number (A) _____

electron arrangement _____

ion _____

isotope _____

Do now

1. **(Last lesson)** Name the three subatomic particles and give the relative charge of each.

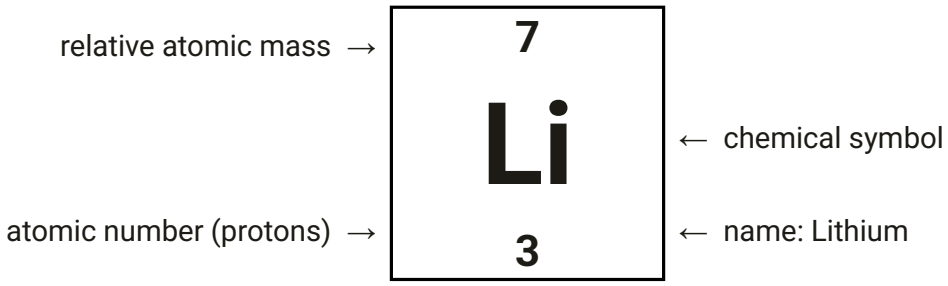
   _____

2. **(This topic)** Where in the atom are (a) protons and (b) electrons found?

   _____

What the numbers mean

Every atom is written as a **symbol** with two numbers. The number on top is the **mass number, A** — the total number of protons and neutrons in the nucleus (also called the **nucleon number**, because protons and neutrons together are called nucleons). The number on the bottom is the **atomic number, Z** (also called the **proton number**) — the number of protons in the nucleus, which is what makes an element that element. Three rules: protons = Z; in a neutral atom electrons = Z; **neutrons = A − Z**.



Relative atomic mass (top) · chemical symbol (middle) · proton number / atomic number (bottom). Neutrons = mass − protons.

WORKED EXAMPLE

The notation for one atom of calcium is $^{40}_{20}\mathrm{Ca}$.

1. **Protons** = Z = **20**
2. **Electrons** = protons (neutral atom) = **20**
3. **Neutrons** = A − Z = 40 − 20 = **20**

DID YOU KNOW?

Carbon comes in different **isotopes** — same element, different numbers of neutrons. Carbon-14 is radioactive, so archaeologists use it to **date** ancient bones and wood (radiocarbon dating). Same Z, different A.

Protons, neutrons & electrons

Complete the table. The first row is done for you.

Atom	Z	A	Protons	Neutrons	Electrons
Lithium $^{7}_{3}\mathrm{Li}$	3	7	3	4	3
Carbon $^{12}_{6}\mathrm{C}$					
Oxygen $^{16}_{8}\mathrm{O}$					
Sodium $^{23}_{11}\mathrm{Na}$					
Potassium $^{39}_{19}\mathrm{K}$					

Now work backwards — fill every gap. Use a periodic table to name the element from its protons.

Element	Z	A	Protons	Neutrons	Electrons
	6	12			
Oxygen		16			

Element	Z	A	Protons	Neutrons	Electrons
		23	11	12	
			9	10	9

Ions and isotopes

When an atom **loses or gains an electron**, it becomes an **ion** — a charged particle. Positive ions have **fewer** electrons than protons (they have lost electrons); negative ions have **more** electrons than protons (they have gained electrons). The charge = protons − electrons. **Isotopes** are atoms of the **same element** with **different numbers of neutrons**. They have the same atomic number (Z) but different mass numbers (A). Because an element is a **mix** of isotopes, the **relative atomic mass** shown on the periodic table is an **average** — which is why many are decimals: chlorine is **35.5**, from a roughly 3:1 mix of chlorine-35 and chlorine-37.

WORKED EXAMPLE

A sodium atom has 11 protons and 11 electrons. It **loses 1 electron** → Na^+: still 11 protons, now 10 electrons, so the charge is **+1**.

Ions & isotopes

1. Give the charge: (a) an atom that **loses 2** electrons (b) an atom that **gains 1** electron.

_____

2. Magnesium loses 2 electrons. Write its ion (symbol with charge): _____
3. Carbon-12 and carbon-14 are isotopes — both have 6 protons. How many **neutrons** does each have?

_____

Arranging the electrons

Electrons sit in **shells** and fill from the inside out: 2, then 8, then 8. We write the arrangement as numbers separated by commas.

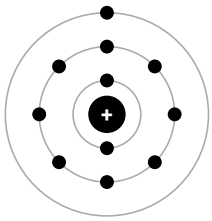
SCOPE — THE EDGE OF THE MODEL

At this level Shells fill 2, then 8, then 8. This rule is correct for every element up to calcium (Z = 20).
Beyond it Past calcium the rule breaks down: the third shell can hold **18** electrons, and shells begin to fill out of order. That is why the Bohr diagrams in this book stop at element 20.

Not assessed. Every Bohr diagram you are asked for stops at calcium.

WORKED EXAMPLE

Sodium (Z = 11): 2 in the first shell, 8 in the second, 1 left over → **2, 8, 1**. The single outer electron is why sodium is in Group 1.

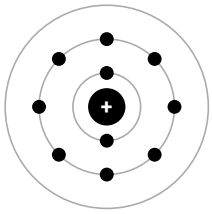


Na · 2, 8, 1

COMPLETE THE MODEL

Magnesium (Z = 12). The inner shells are already drawn — add the **outer** electrons, then write the arrangement.

Electron arrangement = _____



magnesium · complete it

Check

1. An atom is $^{19}_{9}\mathrm{X}$. How many **neutrons**? A. 9 B. 10 C. 19 D. 28
2. An atom has arrangement **2, 8, 6**. Its atomic number is: A. 6 B. 8 C. 16 D. 26
3. Which arrangement is an **unreactive** element? A. 2,8,1 B. 2,8,7 C. 2,8,8 D. 2,8,3

Go further (digital edition / visualiser — click to open): BUILD AN ATOM QUIZ 1

1.5 The Periodic Table — groups & periods

Key words

Write what each word means as we meet it.

group _____

period _____

metal / non-metal _____

noble gas _____

Do now

1. Write the electron arrangement of (a) carbon (Z = 6) and (b) neon (Z = 10).

   _____

2. Which of the two has a full outer shell?

   _____

How the table is organised

The Periodic Table organises the elements in order of their atomic number. Vertical columns of elements are referred to as **groups** — elements in the same group have the same number of outer-shell electrons and therefore have similar physical and chemical properties. Horizontal rows of elements are referred to as **periods**. **Metals** are found toward the left and centre; **non-metals** toward the right.

The **noble gases** (He, Ne, Ar, Kr, Xe and Rn) are very stable because they have **complete outer shells of electrons** and are unlikely to lose or gain electrons — this is why they are very unreactive. They are in **Group 18** (older books number this group as Group 0).

SCOPE — THE EDGE OF THE MODEL

At this level Noble gases are **very unreactive**, because their outer shell is already full.

Beyond it Unreactive is not the same as impossible. In 1962 Neil Bartlett made xenon react, and compounds such as XeF_4 have been made since. Older books call Group 18 the “inert gases”; that name was dropped when the evidence changed.

Not assessed. Treat Group 18 as unreactive in every question.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1																	4 **He** 2
2	7 **Li** 3	9 **Be** 4											11 **B** 5	12 **C** 6	14 **N** 7	16 **O** 8	19 **F** 9	20 **Ne** 10
3	23 **Na** 11	24 **Mg** 12											27 **Al** 13	28 **Si** 14	31 **P** 15	32 **S** 16	35.5 **Cl** 17	40 **Ar** 18
4	39 **K** 19	40 **Ca** 20	45 **Sc** 21	48 **Ti** 22	51 **V** 23	52 **Cr** 24	55 **Mn** 25	56 **Fe** 26	59 **Co** 27	58 **Ni** 28	64 **Cu** 29	65 **Zn** 30	70 **Ga** 31	73 **Ge** 32	75 **As** 33	79 **Se** 34	80 **Br** 35	84 **Kr** 36
5	85 **Rb** 37	88 **Sr** 38	89 **Y** 39	91 **Zr** 40	93 **Nb** 41	96 **Mo** 42	[98] **Tc** 43	101 **Ru** 44	103 **Rh** 45	106 **Pd** 46	108 **Ag** 47	112 **Cd** 48	115 **In** 49	119 **Sn** 50	122 **Sb** 51	128 **Te** 52	127 **I** 53	131 **Xe** 54
6	133 **Cs** 55	137 **Ba** 56	175 **Lu** 71	178 **Hf** 72	181 **Ta** 73	184 **W** 74	186 **Re** 75	190 **Os** 76	192 **Ir** 77	195 **Pt** 78	197 **Au** 79	201 **Hg** 80	204 **Tl** 81	207 **Pb** 82	209 **Bi** 83	[209] **Po** 84	[210] **At** 85	[222] **Rn** 86
7	[223] **Fr** 87	[226] **Ra** 88	[262] **Lr** 103	[267] **Rf** 104	[270] **Db** 105	[271] **Sg** 106	[270] **Bh** 107	[277] **Hs** 108	[278] **Mt** 109	[281] **Ds** 110	[282] **Rg** 111	[285] **Cn** 112	[286] **Nh** 113	[289] **Fl** 114	[290] **Mc** 115	[293] **Lv** 116	[294] **Ts** 117	[294] **Og** 118

*	139 **La** 57	140 **Ce** 58	141 **Pr** 59	144 **Nd** 60	[145] **Pm** 61	150 **Sm** 62	152 **Eu** 63	157 **Gd** 64	159 **Tb** 65	163 **Dy** 66	165 **Ho** 67	167 **Er** 68	169 **Tm** 69	173 **Yb** 70
**	[227] **Ac** 89	232 **Th** 90	231 **Pa** 91	238 **U** 92	[237] **Np** 93	[244] **Pu** 94	[243] **Am** 95	[247] **Cm** 96	[247] **Bk** 97	[251] **Cf** 98	[252] **Es** 99	[257] **Fm** 100	[258] **Md** 101	[259] **No** 102

☐ metals ☐ metalloids ☐ non-metals ☐ noble gases

The bold **staircase** line separates metals (left) from non-metals (right).

Groups run down (1–18); **periods** run across (1–7). Each cell shows: relative atomic mass (top) · symbol (middle) · proton number (bottom). Colours group the elements. A full-page copy is in the appendix.

Check the key first. Other books arrange the square differently (they often swap the two numbers), use different group labels (1–18 vs older Roman numerals or Group 0) and even spell names differently — same elements, different model. See *Models don’t always agree* in the appendix.

Metals vs non-metals — key physical properties

Properties of a typical metal (solid)	Properties of a typical non-metal (solid)
Good conductor of electricity	Poor conductor of electricity
Good conductor of heat	Poor conductor of heat
Shiny surface	Dull surface
High density	Low density
Malleable and ductile	Brittle

DID YOU KNOW?

When Mendeleev built his table in 1869 he left **gaps** for elements not yet discovered — and predicted their properties. Gallium and germanium were later found almost exactly as he described. **A good model predicts.**

Reading the table

Use a periodic table to complete:

Element	Group	Period	Metal or non-metal?
Sodium (Na)			
Chlorine (Cl)			
Magnesium (Mg)			
Argon (Ar)			

Explain. Lithium and sodium are both in Group 1. Why do they react in similar ways?

Noble gas uses. Their unreactive nature influences their uses. Match each noble gas to its use.

Noble gas	Use — choose from the list
Helium	
Neon	
Argon	
Krypton / Xenon	

Uses: in balloons and airships (less dense than air, does not burn) · glowing advertising signs and fluorescent lights · inert atmosphere in welding · flash bulbs and laser beams

Check

1. Elements in the same **group** have the same number of: A. neutrons B. shells C. outer electrons D. protons
2. Metals are found mainly on the: A. left & centre B. right C. top D. bottom
3. Noble gases (Group 18) are unreactive because they have: A. no electrons B. a full outer shell C. many shells D. no nucleus

1.6 Reactivity trends — groups 1, 2 & 17

Key words

Write what each word means as we meet it.

reactivity _____

alkali metal (Group 1) _____

alkaline earth metal (Group 2) _____

halogen (Group 17) _____

Do now

1. Write the electron arrangements of lithium (Z = 3) and sodium (Z = 11).

   _____

2. How many electrons does each have in its outer shell?

   _____

Patterns in reactivity — Groups 1, 2 and 17

Group 1 — alkali metals. The atoms of Group 1 metals all have **one** electron in their outer shell. In Group 1, the further **down** the group the **more** reactive the alkali metal (Li < Na < K). The alkali metals react exothermically with water (an **exothermic** reaction **releases heat** to the surroundings — the water gets warm), fizzing and releasing **hydrogen gas** and forming soluble alkaline **hydroxides**.

e.g. sodium + water → sodium hydroxide + hydrogen

Group 2 — alkaline earth metals. Group 2 metals are also fairly reactive. They react in air to form oxides, in water to form hydroxides, and in acids to form salts. Calcium reacts vigorously in cold water, producing **calcium hydroxide** and **hydrogen gas**; magnesium reacts much more slowly in water, but reacts readily in acid. Reactivity **increases** down Group 2, reflecting the same trend as Group 1.

calcium + water → calcium hydroxide + hydrogen magnesium + hydrochloric acid → magnesium chloride + hydrogen

Group 17 — halogens. The elements in Group 17 have just one valence electron missing from their outer shell. The nucleus has a strong pull on electrons and they react by **gaining** one electron from other atoms. The

reactivity **decreases** down the group with F, fluorine, the most reactive (and quite dangerous!) element (F > Cl > Br).

We explain all three trends with electron arrangements: a Group 1 or 2 atom loses its outer electron(s) more easily when the outer shell is **further from the nucleus**; a Group 17 atom gains an electron less easily for the same reason.

Group 1 (alkali metals)

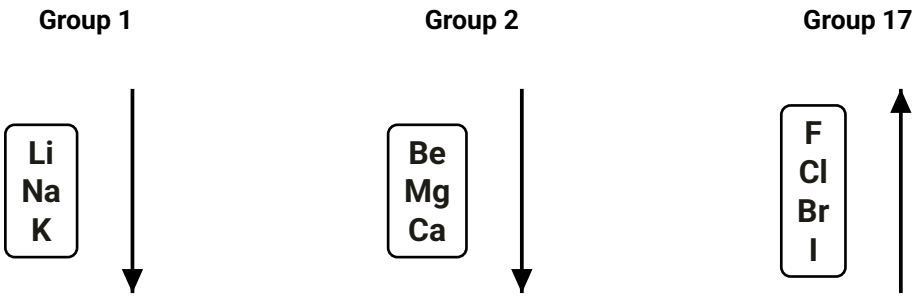
React with water, fizzing and producing hydrogen gas. Reactivity **increases** down the group.

Group 2 (alkaline earth metals)

React in water and acid to produce hydrogen gas. Reactivity **increases** down the group.

Group 17 (halogens)

Coloured, diatomic (Cl_2, Br_2, I_2). Reactivity **decreases** down the group.



reactivity **increases** down — the outer electron is lost more easily

reactivity **increases** down — same reason as Group 1

reactivity **decreases** down — an electron is gained less easily

The arrow shows the direction of *increasing* reactivity in each group.

tape in / sketch your photo here

Teacher demo — alkali metal in water. Record what you **observe** (movement, fizzing, flame, the indicator colour) and name the gas produced.

DID YOU KNOW?

Drop **caesium** (Group 1, low down) in water and it reacts **explosively** — far more violently than lithium at the top. The trend you predict on paper plays out dramatically in the lab.

Practical — reactions of calcium and magnesium (Group 2)

Aim: To explore the reactions of Group 2 metals and compare their reactivity. ≈ 30 min

Apparatus: boiling tube + rack, thermometer, forceps/tongs, test tubes, spatula, calcium pieces, magnesium pieces, dilute hydrochloric acid, distilled water. (Teacher demo: trough, inverted funnel, bung, splints.)

Safety: Wear a lab coat and goggles at all times. The acid is corrosive. Tie back long hair near flames. Wash your hands at the end.

Part 1 — Calcium in water: Half-fill a boiling tube with water and record the temperature. Using forceps, add two pieces of calcium and **keep the tube in the rack**. Stir gently and record the **highest** temperature reached. Watch the fizzing — a gas is being produced.

Teacher demo — testing the gas: Because the gas escapes an open tube too quickly to test, your teacher collects it over an **upturned funnel** in a water trough, seals it with a bung, then ignites it with a lit splint — a **squeaky pop** confirms the gas is **hydrogen**.

Part 2 — Magnesium in acid: Add a small spatula of magnesium pieces to about 3 cm depth of hydrochloric acid in a test tube. Note how vigorous the reaction is compared with calcium in water.

Results and questions:

Temperature of cold water _____ °C Highest temperature _____ °C Temperature rise _____ °C

Describe what you observed when calcium was added to water.

Give the **word equation** for calcium reacting with water.

Give the **word equation** for magnesium reacting with hydrochloric acid.

Predict what would happen if magnesium was added to water instead of acid. Give a reason.

Practical — flame tests (identifying metals)

Aim: To use flame colours to identify the metal in a compound, and link the colour to the element. ≈ 15 min

Apparatus: Bunsen burner, nichrome (or clean) wire loop, watch glasses of metal salts (lithium, sodium, potassium, calcium, copper), dilute hydrochloric acid to clean the wire, heat-proof mat.

Safety: Wear goggles. Open flame — tie back long hair. The metal salts and acid are irritants; wash your hands afterwards.

Method:

1. Light the Bunsen and open the air hole for a roaring blue flame.
2. Dip the clean wire loop in hydrochloric acid, then into the first salt.
3. Hold it at the **edge** of the blue flame and record the colour.
4. Clean the wire in acid until the flame is colourless again before the next salt.

Results:

Metal salt	Flame colour
Lithium	
Sodium	
Potassium	
Calcium	
Copper	

Some fireworks glow red, others lilac or green. Using your results, suggest which metals might be used to colour them.

Practical — displacement reactions (the reactivity series)

Aim: To work out the order of reactivity of four metals by seeing which displacements take place. **≈ 25 min**

Apparatus: spotting tile, dropper pipettes, solutions of zinc sulfate, magnesium sulfate, copper sulfate and iron sulfate, and pieces of zinc, magnesium, copper and iron.

Safety: Wear goggles. Copper sulfate solution is harmful — do not get it on your skin; wash your hands after.

A **more reactive** metal will **displace** a less reactive metal from its compound. If you add a metal to the salt of a less reactive metal, a reaction happens (a colour change, a coating on the metal, or warming).

Method: put a few drops of each solution along a row of wells. Add one piece of each metal to the solutions — but **not** the metal that matches the solution. Record where a reaction takes place.

Metal ↓ · Solution →	Zinc sulfate	Magnesium sulfate	Copper sulfate	Iron sulfate
Zinc	—			
Magnesium		—		
Copper			—	

Iron				—

Put the four metals in order, **most reactive** first.

Give the **word equation** for magnesium reacting with copper sulfate.

Predict & explain

1. Put these in order of **increasing** reactivity: potassium, lithium, sodium.
2. Explain, using outer electrons and shells, **why** potassium is more reactive than lithium.
3. Predict whether fluorine or iodine is more reactive, and explain.
4. Predict and explain whether calcium or magnesium would react more vigorously in water.

Check

1. Down Group 1, reactivity: A. increases B. decreases C. stays same D. varies
2. Down Group 17, reactivity: A. increases B. decreases C. stays same D. varies
3. Group 1 metals react by **losing** how many electrons? A. 0 B. 1 C. 2 D. 7

1.7 Physical & chemical change

Key words

Write what each word means as we meet it.

physical change _____

chemical change _____

reactant / product _____

state symbol _____

law of conservation of mass _____

Do now

1. Name the change of state when a liquid turns to a gas.

   _____

2. Is melting ice a physical or a chemical change? Why?

   _____

Two kinds of change

When a sample of substance undergoes a **physical change**, the movement and arrangement of the particles which make it up both change. The particles themselves, however, remain the same. Changes of state — such as melting, freezing or boiling — are good examples of physical change. No new substance is made and the change can usually be reversed.

When a sample of substance undergoes a **chemical change**, the particles which make up that substance rearrange, and one or more **new substances** are formed. A chemical change is usually difficult to reverse. Signs that a chemical reaction has taken place include: a colour change, a gas given off, a temperature change, or a solid precipitate forming.

What does 'chemically combined' mean? When atoms are chemically combined (or bonded), they are joined together in a way that can only be undone by another chemical reaction — you cannot separate them just by filtering or heating. This is what makes compounds different from mixtures.

We write reactions as **reactants** → **products**. **Reactants** are the substances that react; **products** are the new substances formed.

State symbols and notation

Chemical equations use the formula for the reactants and products to represent the reaction. We also add **state symbols** to show the physical state of each substance:

(s) = solid	(l) = liquid	(g) = gas	(aq) = aqueous solution (dissolved in water)

"Aqueous" just means **dissolved in water**: $CuSO_4$ (aq) is copper sulphate dissolved in water (a blue solution) — not the same as (l), a pure liquid. When an ionic compound dissolves, its ions separate and move freely through the solution (you will build on this in Year 10).

WORKED EXAMPLE

Writing an equation with state symbols:

Solid copper is heated in air (reacting with oxygen gas) to form solid copper oxide:

$2\ Cu_{(s)} + O_{2(g)} \rightarrow 2\ CuO_{(s)}$

Balancing equations

WORKED EXAMPLE

Balance: $H_2 + O_2 \rightarrow H_2O$

There are 2 oxygen atoms on the left, so we need 2 water molecules; that needs 2 hydrogen molecules:

$\mathbf{2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(g)}}$. The same atoms exist before and after — mass is conserved.

From ion charges to a formula

When a metal reacts with a non-metal, the metal atoms **lose** their outer electrons and the non-metal atoms **gain** them — both become **ions**. The **charge** on the ion comes straight from the group:

Group 1 → charge **1+** (Li^+, Na^+, K^+)
Group 2 → charge **2+** (Mg^{2+}, Ca^{2+})
Group 17 → charge **1−** (Cl^-, Br^-)
Group 16 → charge **2−** (O^{2-})

A compound has **no overall charge**, so the total **positive** and **negative** charges must **balance**. That balance is what gives you the formula.

WORKED EXAMPLE

Why LiCl but $MgCl_2$?

Lithium forms Li^+ (1+) and chlorine forms Cl^- (1−). One of each balances (1+ with 1−) → **LiCl**.

Magnesium forms Mg^{2+} (2+). A single Cl^- cancels only half of that, so you need **two** Cl^- ions to balance the 2+ → **$MgCl_2$**.

The law of conservation of mass

Around the turn of the 17th century, the French chemist **Antoine Lavoisier** recognized that the **total mass of the product(s) of a chemical reaction is always equal to the total mass of the reactant(s)**. His idea was accepted by the scientific community and became known as the **law of conservation of mass**.

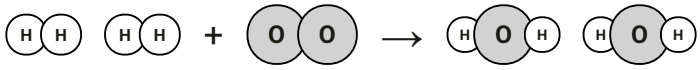
SCOPE — THE EDGE OF THE MODEL

At this level In a chemical reaction, mass is **always** conserved. Atoms are rearranged, never created or destroyed, and every calculation in this unit relies on it.

Beyond it In **nuclear** reactions a small amount of mass is converted into energy ($E = mc^2$), which is how the Sun releases its energy. The amount is far too small to detect in any chemical reaction.

Not assessed in chemistry. You will meet $E = mc^2$ in physics.

A few decades later, British chemist **John Dalton** explained why: when chemical reactions take place, the atoms which make up the reactants are separated and recombined to produce new particles. Overall, the **total number and type of each atom present before, during and after the reaction must remain the same** — and therefore mass too must be conserved.



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

The **same atoms** (4 H, 2 O) appear before and after — just **rearranged** into new molecules. Nothing is created or destroyed, so the **mass is conserved**.

Practical — conservation of mass

Aim: To test Lavoisier's law of conservation of mass by reacting hydrochloric acid with sodium hydrogen carbonate. ≈ 25 min

Apparatus: small conical flask, weighing boat, balance, measuring cylinder, balloon, dilute hydrochloric acid, sodium hydrogen carbonate ($NaHCO_3$). (Simpler alternative: an effervescent tablet in water.)

Safety: Wear goggles. The acid is corrosive — wipe up spills. Do not seal the flask so tightly that pressure builds up.

$HCl_{(aq)} + NaHCO_{3(s)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

Before you start — count the atoms on each side, so you can predict what should happen to the mass:

Atom	Reactants (left)	Products (right)
Carbon (C)		
Oxygen (O)		
Hydrogen (H)		
Sodium (Na)		
Total		

Experiment 1 (open flask): Zero the balance with an empty flask and weighing boat. Add hydrochloric acid (15 ml) to the flask and several spatulas of sodium hydrogen carbonate to the weighing boat. Record the total mass, then tip the $NaHCO_3$ into the acid. Record the final mass.

Experiment 2 (sealed with a balloon): Repeat, but put the $NaHCO_3$ in a balloon fitted over the flask's mouth so that all the gas is captured, then tip it in. Record the initial and final mass.

Results and analysis:

In which experiment was there a greater change in mass? Can you suggest why?

Do your results support Lavoisier's law? Explain, using your atom count.

DID YOU KNOW?

A rusting iron nail gets **heavier**, not lighter — because iron atoms combine with oxygen from the air. This perfectly illustrates the law of conservation of mass: mass is not lost, it is just rearranged.

Practical — a copper cycle (three reactions)

Aim: To observe the evidence for chemical change through a sequence of reactions, and think about how the atoms are rearranged each time.

≈ 45 min

Apparatus: clamp stand, test tube, Bunsen, heat-proof mats, spatula, copper carbonate; then tripod + gauze, 100 ml beaker, watch glass, glass rod, 25 ml measuring cylinder, dilute sulphuric acid; then conical flask, funnel, filter paper, petri dish, magnesium pieces.

Safety: Wear a lab coat and goggles. Open flame and hot apparatus — do not touch the tripod or gauze. Sulphuric acid is corrosive; copper compounds are harmful. Tie back long hair. Do not eat or drink in the lab.

Set out a page to record, for each part, your **evidence for a chemical reaction** and a **word** and **balanced symbol** equation.

Reaction 1 — Heating copper carbonate: Clamp a test tube at an angle and add two spatulas of green copper carbonate. Heat with a blue flame until there is no more change (it won't take long), then let it cool.

Describe the colour change. How do you know a chemical reaction has taken place?

Word equation: copper carbonate → copper oxide + carbon dioxide

Balanced symbol equation: $CuCO_{3(s)} \rightarrow$ _____

Reaction 2 — Copper oxide with sulphuric acid: Tip the cooled black copper oxide onto a watch glass. Add 20 ml of sulphuric acid to a beaker and warm it gently on a tripod and gauze (do **not** boil). Add the copper oxide a little at a time, stirring, until it dissolves. If the solution stays murky grey, filter it.

Describe what you observe (colour of the solution).

Word equation: copper oxide + sulphuric acid → copper sulphate + water

Balanced symbol equation (the SO_4 part does not change):

Reaction 3 — Copper sulphate with magnesium: Add a few pieces of magnesium to your blue copper sulphate solution and leave it to react. When it stops, filter out the solid, put it on a petri dish and **leave it to dry until next lesson**.

What forms on the magnesium, and what happens to the blue colour? Suggest where the copper came from.

Balanced symbol equation: $CuSO_{4(aq)} + Mg_{(s)} \rightarrow$ _____

For all three reactions: include state symbols, and explain how each observation tells you a chemical reaction has occurred.

Classify & balance

1. Physical or chemical? (a) frying an egg (b) snapping a stick (c) a firework (d) dissolving sugar.

2. Balance and add state symbols: $Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$

3. Balance and add state symbols: $Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$

4. Write the word equation for the following, then write the balanced symbol equation with state symbols: (a) Zinc metal reacts with a solution of hydrochloric acid to form soluble zinc chloride and hydrogen gas.

   (b) Calcium reacts with water to form calcium hydroxide and hydrogen gas.

5. Give the **ion charge** of each, using its group: sodium, calcium, chlorine, oxygen.

6. Work out the **formula** of (a) sodium chloride (b) calcium chloride (c) magnesium oxide (d) potassium oxide.

7. Explain, using ion charges, why magnesium chloride is $MgCl_2$ and not MgCl.

Check ✓

1. A **chemical** change always: A. is reversible B. makes a new substance C. changes state D. dissolves
2. In a sealed flask, the mass after a reaction is: A. less B. more C. the same D. zero
3. The state symbol (aq) means: A. solid B. liquid C. gas D. dissolved in water

1.8 Rates of reaction

Key words

Write what each word means as we meet it.

rate of reaction _____

collision theory _____

catalyst _____

Do now

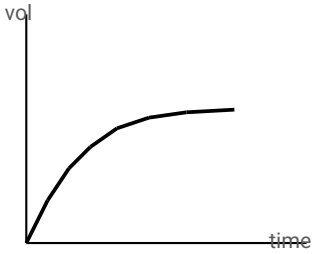
1. Give one everyday example of a **fast** reaction and one **slow** reaction.

_____

How fast, and why

We call how fast a chemical reaction is happening the **rate of the reaction**. This is defined as the **change in the concentration of reactant or product over time**. (**Concentration** = how much dissolved substance there is in a given volume — a more concentrated acid has more acid particles in the same space.) A faster reaction produces products more quickly and uses up reactants more quickly.

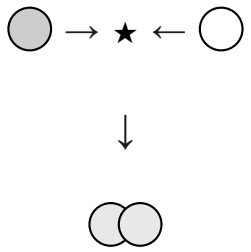
Collision theory explains why rate changes: for a reaction to happen, the particles must **collide** with each other as **successful collisions** — meaning they must have enough energy to react. To increase the rate of a reaction, we can increase the rate at which successful collisions occur. The main factors are **concentration**, **temperature** and **surface area** (and **catalysts**).



volume of gas vs time

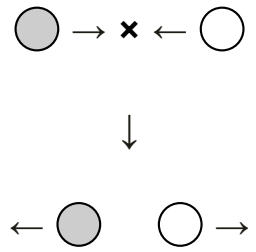
Reading a rate graph: a **steeper** line means a **faster** rate. The line levels off when a reactant runs out and the reaction stops. The **steepest part is at the start**, when concentration is highest.

Successful collision



Enough energy → the particles **react** and a new product forms.

Unsuccessful collision



Too little energy → they just **bounce off**, unchanged.

Criterion B/C — the rates investigation

This is the one time in the unit you **behave like a scientist** and design the experiment yourself. It runs over **four lessons**: you **plan** it (Criterion B), **carry it out**, then **process and evaluate** your data (Criterion C).

L25 · lesson	L26 · lesson	L27 · lesson	L28 · lesson
1. Plan (Crit B)	**2. Carry out**	**3. Process data**	**4. Evaluate (Crit C)**

The reaction. Sodium thiosulphate reacts with hydrochloric acid to make a pale-yellow **sulfur precipitate** that slowly clouds the solution. Stand the flask on a paper cross and time how long the cross takes to **disappear** — a shorter time means a faster rate.

$Na_2S_2O_{3(aq)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + S_{(s)} + SO_{2(g)} + H_2O_{(l)}$

Research question: How does the **concentration** of sodium thiosulphate affect the rate of its reaction with hydrochloric acid?

Hypothesis — what relationship do you expect between concentration and rate?

Reason — explain your prediction using **collision theory** (particles, successful collisions).

Variables — how will you make it a fair test?

Independent (what you **change**) and its range:

Dependent (what you **measure**) and exactly how:

Controlled (kept the **same**, and how):

What to keep the same	How you will control it

Equipment (list the apparatus and the exact volumes/amounts):

Safety (hazard → what you will do):

Method — numbered steps saying exactly what to do and what to record. **Don't forget to repeat your readings.**

Results — record your data in a neat table (clear headings and units; include your repeats and a mean):

Concentration	Time 1 (s)	Time 2 (s)	Mean time (s)

Graph — plot your results (rate, or 1 ÷ time, against concentration). Attach or draw it here, with labelled axes and a line of best fit.

Conclusion — describe the trend in detail, then say whether your hypothesis was supported.

Evaluation — how reliable was your method? Give a problem, its effect, and an improvement:

Problem with the method	How it affected the results	Improvement

Marked on: Criterion B (asking a question, hypothesis, variables, a safe method) at the **plan** stage; Criterion C (collecting, presenting and interpreting data; validity; improvements) at the **process & evaluate** stage.

DID YOU KNOW?

Surface area matters a lot: a solid lump of flour barely burns, but flour **dust** has so much surface area that flour mills have exploded. Catalytic converters use **catalysts** to speed up clean-up reactions in cars.

Interpret & plan

1. On the graph above, mark with an **X** where the reaction is **fastest**. Explain your choice.

2. Name the three main factors that affect rate, and for each say **why** (using collisions).

Check

1. Particles must collide with enough: A. mass B. energy C. charge D. colour
2. Increasing temperature makes the rate: A. faster B. slower C. stop D. no change
3. A **catalyst**: A. is used up B. speeds a reaction up C. slows it down D. is a product

Assessments

This unit is assessed against all four MYP Sciences criteria. Use this page to keep track.

Criterion	Task	When	Done
A — Knowing & understanding	End-of-unit test (atoms, periodic table, reactions)	mid-unit	☐
B — Inquiring & designing	Plan the rates-of-reaction investigation	late unit	☐
C — Processing & evaluating	Process & evaluate your investigation data	late unit	☐
D — Reflecting on impacts	“Impactful Elements” research & debate project	across unit	☐

HOW TO REVISE (CRITERION A)

Make a one-page **knowledge organiser** of the facts in each section, then test yourself with the **Check** questions and the key-word definitions. Retrieval beats re-reading.

Self-check before the test ✓

Tick when you can do each without notes:

Classify matter; element / compound / mixture	☐
Read symbols & formulae; count atoms	☐
Describe the atom & the Bohr model	☐
Use A-Z-X notation; find p / n / e; write electron arrangements	☐
Use the Periodic Table; groups, periods, metals	☐
Explain reactivity trends in groups 1, 2 & 17	☐
Physical vs chemical change; balance equations with state symbols	☐
Rates of reaction & collision theory	☐

Appendix — The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** Hydrogen 1																	4 **He** Helium 2
2	7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
3	23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
4	39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	58 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
5	85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	[98] **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
6	133 **Cs** Caesium 55	137 **Ba** Barium 56	175 **Lu** Lutetium 71	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	[209] **Po** Polonium 84	[210] **At** Astatine 85	[222] **Rn** Radon 86
7	[223] **Fr** Francium 87	[226] **Ra** Radium 88	[262] **Lr** Lawrencium 103	[267] **Rf** Rutherfordium 104	[270] **Db** Dubnium 105	[271] **Sg** Seaborgium 106	[270] **Bh** Bohrium 107	[277] **Hs** Hassium 108	[278] **Mt** Meitnerium 109	[281] **Ds** Darmstadtium 110	[282] **Rg** Roentgenium 111	[285] **Cn** Copernicium 112	[286] **Nh** Nihonium 113	[289] **Fl** Flerovium 114	[290] **Mc** Moscovium 115	[293] **Lv** Livermorium 116	[294] **Ts** Tennessine 117	[294] **Og** Oganesson 118

*	139 **La** Lanthanum 57	140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	[145] **Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	163 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70
**	[227] **Ac** Actinium 89	232 **Th** Thorium 90	231 **Pa** Protactinium 91	238 **U** Uranium 92	[237] **Np** Neptunium 93	[244] **Pu** Plutonium 94	[243] **Am** Americium 95	[247] **Cm** Curium 96	[247] **Bk** Berkelium 97	[251] **Cf** Californium 98	[252] **Es** Einsteinium 99	[257] **Fm** Fermium 100	[258] **Md** Mendelevium 101	[259] **No** Nobelium 102

☐ alkali metals ☐ alkaline earth ☐ transition metals ☐ other metals ☐ metalloids

☐ non-metals ☐ halogens ☐ noble gases ☐ lanthanides ☐ actinides

Each cell: relative atomic mass (top) · symbol · name · proton number (bottom). UK/IGCSE convention. Masses are standard rounded values used in school science.

Models don’t always agree

A periodic table is a **model** — and different books draw the **same** element differently. Here is chlorine, from this book and from a common online table. The chemistry is identical; only what they choose to show is different.

This book (UK / IGCSE)

35.5
Cl
17

relative atomic mass on top · proton number on the bottom

A common online table

17
Cl
Chlorine
35.45
2, 8, 7

atomic number on top · name, atomic weight & electrons-per-shell below

Spot the differences — same atom, different square

1. **The two numbers are swapped.** This book puts the **mass on top** and the **proton number (17) on the bottom**; the online table puts the **atomic number on top** and the **atomic weight at the bottom**. Always read the **key**, not the position.
2. **One number is a decimal — and that is not a mistake.** 35.5 (or 35.45) is the **relative atomic mass**: an **average** over chlorine’s isotopes (about ¾ chlorine-35 and ¼ chlorine-37). No single atom weighs 35.5 — a real chlorine atom is Cl-35 **or** Cl-37. The **mass number** of one atom is always a **whole number**.
3. **Group labels differ.** This book uses **1–18**; older books use Roman numerals (VIIA) and call the noble gases **Group 0** instead of Group 18.
4. **Spellings differ.** You will also see **sulfur / sulphur** and **aluminium / aluminum** — same element.

So which one is right? Both. They describe the same atom; they just choose different information and layout. That is what a model is — a **choice about what to show**. A good scientist checks the key before trusting any table.

Now you — magnesium, both ways

24.3
Mg
12

12
Mg
Magnesium
24.305
2, 8, 2

Same two differences: the two numbers are **swapped**, and one book **rounds** the mass (24.3) while the other prints the **full average** (24.305). **Circle the proton number** in each square — it is the whole number, and it is 12 in both.

DID YOU KNOW?

Where does 35.45 come from? Bodies like **IUPAC** and the US's **NIST** publish the agreed relative atomic masses, measured from the mix of isotopes found on Earth. When that mix is re-measured, the numbers on the periodic table can shift slightly — the model is kept up to date.

Check

1. In the online square, **which number is the proton number**, and how can you tell?

2. Explain why the relative atomic mass of chlorine (35.5) is **not a whole number**.

About this book — design & features

How this workbook is built, and the thinking behind it. (This page is for reference — you don't have to print it.)

The section icons

- ▶ **Do now** — retrieve from memory first
- **Learn** — read & study, with worked examples
- **Investigate** — simulation / practical
- **Did you know?** — a fact, history or extension
- **Key words** — vocabulary to master
- **Practise** — your turn to write
- **Check** — a quick question to test yourself

The design principles behind this book

Explicit teaching	Every section runs **retrieve** → **learn** → **practise** → **check**. New ideas are shown with **worked examples** before students try them, so nobody is left to guess.
Retrieval first	Each lesson opens with a **Do now** that recalls earlier work, and **Check** questions act as hinge points — spaced practice is built into the layout.
One idea at a time	The unit follows a single spine: **atoms** → **electron arrangement** → **the periodic table** → **reactivity** → **reactions** → **rates.** Each part links back and forward.
Models, made honest	Diagrams (the Bohr model, the periodic table) are introduced **as models** — useful but simplified. The simple vs full periodic table shows this directly.
Clarity over clutter	Generous space to write, consistent colours for each section type, and clear starts/ends so students always know where they are.
Accessible by design	Colour is **never the only cue**: every periodic-table cell carries its symbol, number and position, the metal/non-metal **staircase** shows the key split by position, and the colour palette is **colour-blind-safe**.
Two editions, one source	A **colour digital** edition and a clean **black-&-white print** edition are built from the **same files**, so they never drift apart. Change a colour or a word once and both update.
On-brand	Built in the official International School of Geneva / Campus des Nations colours and logo.

Pedagogy in a line. Tell them clearly, show them how, let them practise, check they've got it — then come back to it again later. Everything in the layout serves that loop.