

Groups in the periodic table

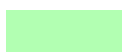
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These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Notes and warnings



Sub-topic headings

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Define Alkali metal

- an element in group 1; a soft metal with a relatively low melting point that reacts with water to form an alkaline solution.

Define Noble gas

- an element in group 0; a chemically inert, monatomic gas with a full outer shell of electrons.

Define Hydrogen halide

- a covalent compound of hydrogen and a halogen (HCl, HBr, HI) that dissolves in water to give an acidic solution.

Oxidation

Reduction

HIGHER TIER

Define HT ONLY

- the gain of electrons.

Define Shielding

- the way inner shells reduce the pull of the nucleus on the outer-shell electrons.

Define Inert

- chemically unreactive; it does not readily take part in chemical reactions.

Define Group

- a vertical column of the periodic table; its elements all have the same number of outer-shell electrons.

Define Halogen

- an element in group 7; a non-metal that exists as diatomic molecules (Cl_2 , Br_2 , I_2) and forms halide ions with a 1- charge.

Define Halide

- the 1- ion formed by a halogen (Cl^- , Br^- , I^-), or a compound containing one.

Define Displacement reaction

- a reaction in which a more reactive element takes the place of a less reactive one in a compound.

HIGHER TIER

Define HT ONLY

- the loss of electrons.

Redox reaction

HIGHER TIER

Define HT ONLY

- a reaction in which oxidation and reduction happen at the same time.

Classifying elements by their position (6.1)

- Elements with **similar chemical properties** share a **group** (vertical column). The **group number** gives the number of **outer-shell electrons**, and those electrons decide how an element reacts — which is why a group behaves alike.
- So you can classify an element from its position alone:
- **group 1**, far left, 1 outer electron → an **alkali metal** (Li, Na, K, Rb, Cs)
- **group 7**, 7 outer electrons → a **halogen** (F, Cl, Br, I, At)
- **group 0**, far right, a full outer shell → a **noble gas** (He, Ne, Ar, Kr, Xe, Rn).
- Going **down** a group each element has **one more occupied shell**, so its outer electrons are further from the nucleus. That single idea explains every reactivity trend in this topic. [6.1]

Group 1 — the alkali metals (6.2–6.5)

Physical properties of the alkali metals (6.2)

- Alkali metals are **soft** — lithium, sodium and potassium can be cut with a knife, giving a shiny surface that quickly tarnishes in air.
- They have **relatively low melting points** for metals (sodium melts at 98 °C); melting point **decreases** down the group. [6.2]
- They have low densities, so they float on water, and they are stored under oil because they react with air and water vapour.

Reactions of lithium, sodium and potassium with water (6.3)

All three give a **metal hydroxide** and **hydrogen**. The hydroxide dissolves, so the solution is **alkaline** — universal indicator turns purple. Hence the name "alkali metal".

Metal	What you see	Speed
Lithium	Floats, fizzes steadily, moves slowly, gradually disappears; no flame	Slowest
Sodium	Floats, fizzes rapidly, melts into a shiny ball that darts about; may burn orange	Faster
Potassium	Floats, reacts violently, ignites at once with a lilac flame , crackles and spits The metals melt because the reaction releases a lot of heat and their melting points are low;	Fastest

potassium releases enough to ignite the hydrogen.

The pattern in reactivity and predicting other alkali metals (6.4)

- **Reactivity increases down group 1** — lithium < sodium < potassium.
- **Predict:** rubidium reacts more violently than potassium, and caesium more violently still (explosive, may shatter the container) — but both still give a metal hydroxide, hydrogen and an alkaline solution. [6.4]

Explaining the pattern using electronic configurations (6.5)

When an alkali metal reacts it **loses its single outer electron** to form a 1+ ion ($\text{Na} \rightarrow \text{Na}^+ + \text{e}^-$). The easier that electron is to lose, the more reactive the metal.

Going down the group:

1. Each atom has **one more occupied electron shell**, so the outer electron is **further from the nucleus**.
2. There are more inner shells **shielding** the outer electron from the positive nucleus.
3. So the **force of attraction between the nucleus and the outer electron is weaker**.
4. The outer electron is **lost more easily**, so the element is **more reactive**. [6.5]

Use the electronic configurations to see it: Li 2,1 (outer electron in shell 2) $\rightarrow$ Na 2,8,1 (shell 3) $\rightarrow$ K 2,8,8,1 (shell 4).

ANALOGY

Think of the outer electron as a coat the nucleus holds on a piece of elastic. In lithium the elastic is short and tight, so the wind cannot pull the coat away; in potassium it is long and slack, so the coat is whipped off at the first gust. Down a group the grip weakens — so group 1 gives its electron up more easily (reactivity **up**), while group 7, which needs to *catch* an electron, holds on less well (reactivity **down**).

Group 7 — the halogens (6.6–6.13)

Colours, states and physical properties (6.6, 6.7)

The halogens are non-metals that exist as **diatomic molecules** — Cl_2 , Br_2 , I_2 .

Halogen	Colour and state at room temperature	Vapour
Chlorine, Cl_2	Pale green (yellow-green) gas	Pale green
Bromine, Br_2	Red-brown liquid	Orange-brown
Iodine, I_2 The trends down group 7: Property	Dark grey, shiny solid Trend down the group	Purple

Property	Trend down the group
Melting point and boiling point	Increase — larger molecules, stronger forces between them
State at room temperature	Gas $\rightarrow$ liquid $\rightarrow$ solid, following the rising boiling points
Colour	Gets darker
Density	Increases
Reactivity	Decreases (see 6.13)

- **Predict:** fluorine is a gas with a lower boiling point than chlorine and a paler (yellow) colour; astatine is a black **solid** with a boiling point above iodine's, and is the **least reactive** halogen. [6.7]

The chemical test for chlorine (6.8)

NOTE

Test for chlorine: hold **damp blue litmus paper** in the gas — chlorine **bleaches** it **white**. (It may turn red briefly first, as chlorine forms an acidic solution in the water on the paper.) The paper must be **damp**; dry litmus is not bleached. [6.8]

Reactions with hydrogen — the hydrogen halides (6.10)

- All three react with hydrogen to form **hydrogen halides**: $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$, $\text{H}_2 + \text{Br}_2 \rightarrow 2\text{HBr}$, $\text{H}_2 + \text{I}_2 \rightarrow 2\text{HI}$.
- The vigour again **decreases down the group**: with hydrogen, chlorine reacts explosively in sunlight, bromine needs heat, and iodine reacts only slowly and incompletely.
- Hydrogen halides are colourless gases with sharp, choking smells that **dissolve in water to form acidic solutions** ($\text{HCl} \rightarrow$ hydrochloric acid, $\text{HBr} \rightarrow$ hydrobromic acid, $\text{HI} \rightarrow$ hydroiodic acid). They have a pH below 7 and turn litmus red, because the hydrogen halide releases H^+ ions in water.
- **Predict**: hydrogen and fluorine react explosively even in the dark, and HF dissolves to give an acidic solution; astatine would react with hydrogen only with great difficulty. [6.10]

Reactions of the halogens with metals (6.9)

Halogens react with metals to form **metal halides** — ionic compounds in which the halogen has become a **halide ion**, charge 1–.

- The pattern: **the reaction becomes less vigorous down the group** — chlorine fastest, bromine less so, iodine only slowly and on strong heating.
- **Predict**: fluorine reacts even more vigorously than chlorine; astatine would barely react at all. [6.9]

Displacement reactions of the halogens (6.11)

A more reactive halogen displaces a less reactive halogen from a solution of its halide — the standard test for the order of reactivity.

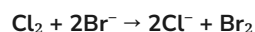
Added to →	Potassium chloride	Potassium bromide	Potassium iodide
Chlorine water	No reaction	Turns orange (Br_2 formed)	Turns brown (I_2 formed)
Bromine water	No reaction	No reaction	Turns brown (I_2 formed)
Iodine solution	No reaction	No reaction	No reaction

- $\text{Cl}_2 + 2\text{KBr} \rightarrow 2\text{KCl} + \text{Br}_2$
- $\text{Cl}_2 + 2\text{KI} \rightarrow 2\text{KCl} + \text{I}_2$
- $\text{Br}_2 + 2\text{KI} \rightarrow 2\text{KBr} + \text{I}_2$
- The order is therefore **chlorine > bromine > iodine**: reactivity **decreases down group 7**.
- **Predict for astatine**: it is the least reactive halogen, so it will **not** displace chloride, bromide or iodide; but iodine would displace it, e.g. $\text{I}_2 + 2\text{KAt} \rightarrow 2\text{KI} + \text{At}_2$. [6.11]

HIGHER TIER**HT ONLY Displacement reactions as redox reactions (6.12)**

HT ONLY In a displacement reaction the halogen **gains** electrons while the halide ion **loses** them, so oxidation and reduction happen together — a **redox** reaction. Remember **OIL RIG**: Oxidation Is Loss, Reduction Is Gain of electrons.

Take $\text{Cl}_2 + 2\text{KBr} \rightarrow 2\text{KCl} + \text{Br}_2$. Potassium ions are spectator ions, so the ionic equation is:



- **HT ONLY** Chlorine **gains** electrons: $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$. Chlorine is **reduced** (it is the oxidising agent).
- **HT ONLY** Bromide ions **lose** electrons: $2\text{Br}^- \rightarrow \text{Br}_2 + 2\text{e}^-$. The bromide ion is **oxidised** (it is the reducing agent).
- **HT ONLY** The more reactive halogen is always the one that is **reduced**, because being reactive means being good at gaining electrons. [6.12]

Explaining halogen reactivity using electronic configurations (6.13)

When a halogen reacts it **gains one electron** into its outer shell to form a 1- ion ($\text{Cl} + \text{e}^- \rightarrow \text{Cl}^-$). The more easily the atom attracts that electron, the more reactive the halogen.

Going down the group:

1. Each atom has **one more occupied electron shell**, so the outer shell is **further from the nucleus**.
2. There is more **shielding** by inner shells.
3. So the **attraction between the nucleus and the incoming electron is weaker**.
4. An electron is **gained less easily**, so the element is **less reactive**. [6.13]

Configurations: F 2,7 (shell 2 is the outer shell) → Cl 2,8,7 (shell 3) → Br 2,8,18,7 (shell 4).

WATCH OUT

Down group 1 reactivity **increases**; down group 7 it **decreases**. The explanation is identical (outer shell further out, more shielding, weaker attraction) — what differs is that group 1 atoms **lose** an electron and group 7 atoms **gain** one. Always say what the atom does with the electron before you give the trend.

Group 0 — the noble gases (6.14–6.16)

Why the noble gases are inert (6.14)

- Noble gases are **chemically inert** — they do not readily react, and they exist as single atoms (monatomic).
- The reason is their **electronic configuration: a full (stable) outer shell** — helium 2, neon 2,8, argon 2,8,8.
- With a full outer shell an atom has **no tendency to lose, gain or share electrons**, and it is the transfer or sharing of outer electrons that makes a reaction happen. Every other element reacts in order to *achieve* the configuration a noble gas already has. [6.14]

- In an exam, name the property **and** link it: "helium is used in balloons because its **low density** makes the balloon rise, and it is **non-flammable**, so it cannot catch fire." [6.15]

Uses of the noble gases (6.15)

Every use follows from a physical or chemical property:

Property	Use
Inertness	Argon in filament bulbs, so the hot filament does not burn away; argon shielding an arc weld, so the hot metal cannot react with oxygen; inert atmospheres for reactive chemicals
Low density	Helium in weather balloons and airships, so they float
Non-flammability	Helium replaced hydrogen in airships — hydrogen burns explosively, helium cannot burn
Inertness in discharge tubes	Neon and the other noble gases glow in advertising signs without attacking the electrodes

The physical properties of the noble gases (6.16)

Noble gas	Boiling point / °C	Density / g dm ⁻³
Helium	-269	0.18
Neon	-246	0.90
Argon	-186	1.78
Krypton	-153	3.75
Xenon	-108	5.90

- **Boiling point increases** down group 0 and **density increases** down group 0 (melting points rise too).
- All are colourless gases at room temperature — every boiling point is far below 0 °C. [6.16] Use the pattern to **predict** the properties of a gas you are not given, such as radon.

ANALOGY

A noble gas atom is the passenger whose suitcase is already exactly full: nothing more will fit and nothing needs taking out, so they walk straight past the check-in desk. Every other element is still frantically swapping items — losing, gaining or sharing electrons — which is exactly what a chemical reaction is.