The periodic table: classification of elements

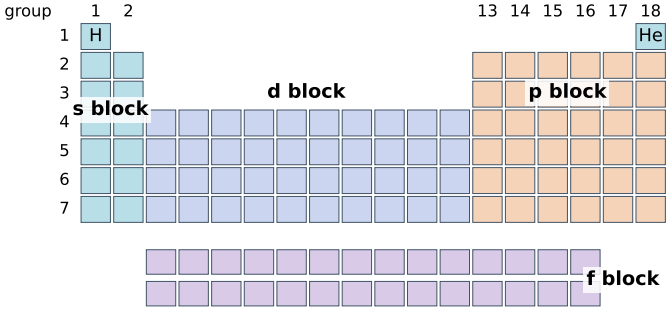
Structure 3.1 · SL and AHL

One table, useful predictions

> A trend is a pattern to explain, with conditions and exceptions.

- Atomic number organizes the modern table.
- Configuration helps explain recurring properties.

Locate periods, groups and blocks



He: group 18, configuration $1s^2$; detached f rows are schematic

Main-group patterns need the helium and hydrogen exceptions.

From position to configuration

1. **Position.** Br: period 4, **group** 17.
2. **Configuration.** [Ar] $3d^{10}4s^{2}4p^{5}$.
3. **Check.** $18 + 10 + 2 + 5 = 35$ electrons.

Decision

Cr and Cu are familiar exceptions to the simple $3d^{n}4s^{2}$ starting pattern.

Explain attraction before naming a trend

Across a main period

Nuclear charge rises; added electrons occupy the same main level.

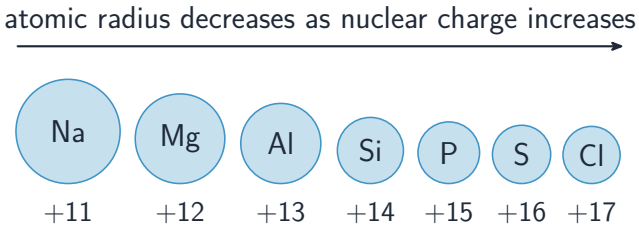
Similar inner **shielding** gives greater attraction overall.

Down a main group

Outer electrons occupy a higher principal level.

Distance and shielding usually outweigh the larger nuclear charge.

Compare atomic radii consistently



Across period 3, increasing nuclear attraction generally contracts the atoms.

Order an isoelectronic set

1. **Electron count.** Mg^{2+}, Na^{+}, F^{-} and O^{2-} all have 10 electrons.
2. **Nuclei.** Their charges are $+12$, $+11$, $+9$ and $+8$.
3. **Increasing radius.** $Mg^{2+} < Na^{+} < F^{-} < O^{2-}$.

Decision

Greater **nuclear charge** contracts the same electron count.

Three different electron questions

Quantity	**What changes?**
first IE	gaseous atom $\rightarrow$ gaseous $1+$ ion $+$ electron
electron-gain enthalpy	gaseous atom $+$ electron $\rightarrow$ gaseous $1-$ ion
electronegativity	attraction for shared density in a bond

An affinity exception: F and Cl

1. **Electron-gain enthalpies.** F -328; Cl -349 kJ/mol.
2. **Compare.** Cl releases 21 kJ/mol more energy.
3. **Explain.** F's compact 2p region increases incoming-electron repulsion.

Decision

A monotonic down-group rule misses the F/Cl exception.

Opposite group trends

Group 1: oxidation

$2Na + 2H_2O \rightarrow 2NaOH + H_2$.

Reactivity generally rises down the **group** as electron loss becomes easier.

Group 17: reduction

$X_2 + 2e^- \rightarrow 2X^-$.

Oxidizing ability generally falls down the group; bonds and solvation also matter.

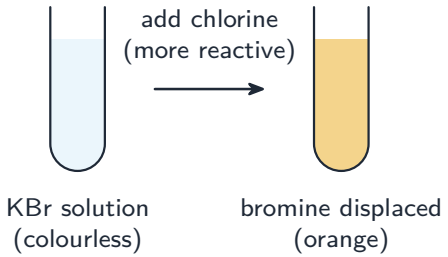
Predict a halide displacement

1. **Equation.** $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$.
2. **Observation.** A brown iodine-containing solution forms.
3. **Reverse?** I_2 does not ordinarily oxidize Cl^- in this displacement test.

Decision

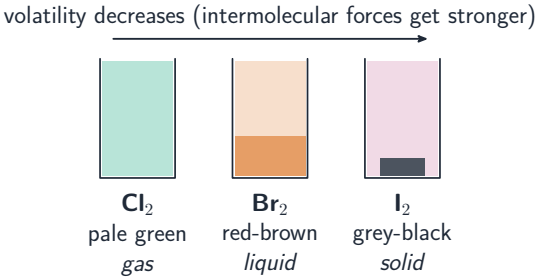
Chlorine is the stronger oxidizing agent under these conditions.

A halogen displacement



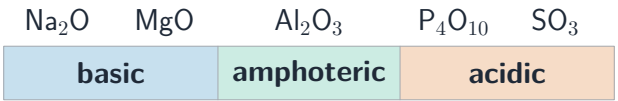
A more reactive **halogen** displaces a less reactive one

The halogens at room temperature



Larger molecules, stronger London forces

Oxide character is not a fixed pH



SiO_2: acidic, but unreactive with water

Solubility, amount and water volume matter for actual pH.

Write oxide–water equations

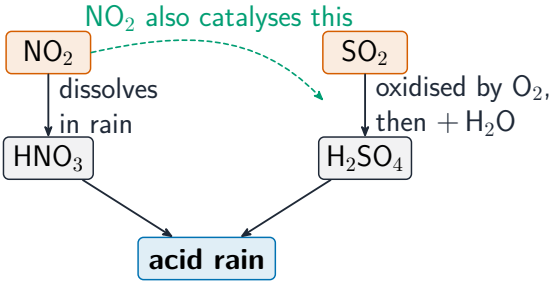
Oxide	Simplified reaction
Na_2O	$Na_2O + H_2O \rightarrow 2NaOH$
CaO	$CaO + H_2O \rightarrow Ca(OH)_2$
CO_2	$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$
SO_3	$SO_3 + H_2O \rightarrow H_2SO_4$

Separate acid deposition and ocean acidification

Acidification is a fall in pH; seawater can remain alkaline.

- Oxidation of SO_2 and nitrogen oxides can form strong acids in rain.
- Dissolved CO_2 increases H^+ and reduces available carbonate.

How acid rain forms



Non-metal oxides are **acidic**

Assign oxidation states by a sum

1. **Species.** $Cr_2O_7^{2-}$ has seven O atoms at -2.
2. **Sum.** $2\mathrm{Cr} - 14 = -2$.
3. **Solve.** $\mathrm{Cr} = +6$; use Roman numerals where needed in naming.

Decision

An uncombined element is 0; inequivalent atoms can give an average state.

Check the usual exceptions

Species	**Sum**	**Result**
NaH	$+1 + \mathrm{H} = 0$	H -1
$\mathrm{H_2O_2}$	$2(+1) + 2\mathrm{O} = 0$	O -1
$\mathrm{OF_2}$	$\mathrm{O} + 2(-1) = 0$	O $+2$

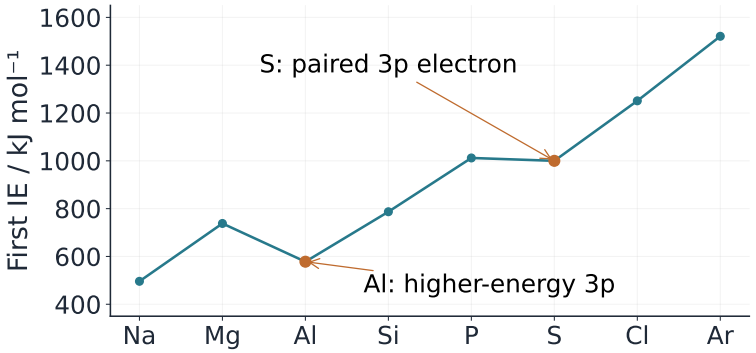
Assigning an oxidation number

known	unknown	known
K	Mn	O_4
$+1$	$+7$	$4 \times (-2)$

they sum to 0: $(+1) + \text{Mn} + (-8) = 0$, so $\text{Mn} = +7$

So Mn is $+7$

AHL: Two period-3 IE dips



Explain the electron removed, rather than invoking “special stability”.

AHL: State the transition criterion

Sc: a classification discussion

Sc atom is $3d^1 4s^2$: included by the broad definition.

Usual Sc^{3+} is d^0, lacking many characteristic transition behaviours.

Characteristic first-row set

Ti–Cu often form the school examples.

Name the criterion instead of contradicting the atom-or-cation definition.

AHL: Ion configurations and complex charge

1. **Species.** $[Fe(CN)_6]^{3-}$: six CN^- ligands give -6.
2. **Metal.** Fe is $+3$; Fe^{3+} is [Ar] $3d^5$.
3. **Coordination.** Six directly attached donor atoms: **coordination number** 6.

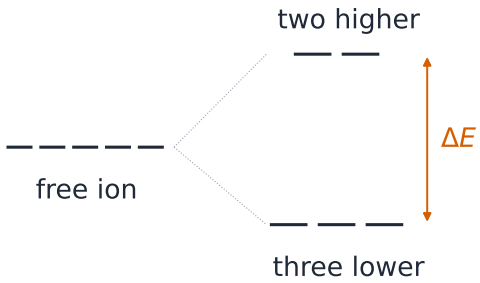
Decision

A d^5 count alone does not determine pairing in every **ligand** field.

AHL: Recognize characteristic properties

Property	**Structural or chemical explanation**
high melting points	strong metallic cohesion, with variation
variable states	outer s/d removals before the major core gap
complex formation	**ligand** donor pairs bond to the metal
catalysis	surface pathways or reversible redox cycles

AHL: Absorb light across a d-orbital gap



octahedral complex: ligands split the d orbitals

absorbs light of energy ΔE

The transmitted colour is complementary to the absorbed colour.

AHL: Use the absorbed wavelength

1. **Given.** Invented absorption: 620 nm; $c = 3.00 \times 10^{8}$ m/s; $h = 6.63 \times 10^{-34}$ J s.
2. **Convert.** 620 nm $= 6.20 \times 10^{-7}$ m.
3. **Frequency.** $f = c/\lambda = 4.84 \times 10^{14}$ Hz.
4. **Photon energy.** $E = hf = 3.21 \times 10^{-19}$ J.

Decision

These are absorbed-light quantities; the blue solution need not emit blue photons.

AHL: Keep the limits of d-electron models

Magnetic examples

High-spin Fe^{3+} d^5 has five unpaired electrons.

A strong field can change the pairing; d count alone is insufficient.

Common colourless examples

Simple Sc^{3+} d^0 and Zn^{2+} d^{10} complexes are often colourless.

Do not generalize this to every compound with those counts.

Properties of transition elements

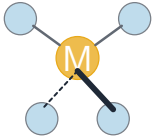
- variable oxidation states
- act as catalysts
- form complex ions
- coloured compounds

> All come from the partly filled d sublevel

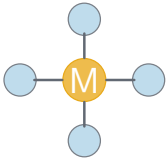
Shapes of complex ions



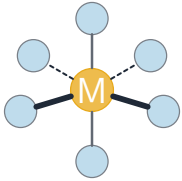
linear
CN 2



tetrahedral
CN 4



square planar
CN 4



octahedral
CN 6

The **coordination number** counts the dative bonds

Exam tips

> Support the claim with the particles, energy change and conditions involved.

- Use the actual configuration and a consistent sign convention.
- Balance equations; do not invent concentrations or exact pH values.

Check yourself

Apply the explanation

Explain the He group/block exception and order the ten-electron ions by radius.

Balance a halogen displacement and distinguish acidification from pH below 7.

Find H in NaH and O in H_2O_2 and OF_2.

AHL. Explain the two IE dips and calculate absorbed frequency from 620 nm.