Structure 1.3 · Electron configurations · supported focus

International Baccalaureate · IB Diploma · Chemistry · SL

Scope and prerequisites

Supported SL core focus. First assessment 2025; current brief acquired; full Chemistry guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: atomic number and the structure of the atom from Structure 1.2, arithmetic with powers of ten, and the wave relation $c = f\lambda$. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

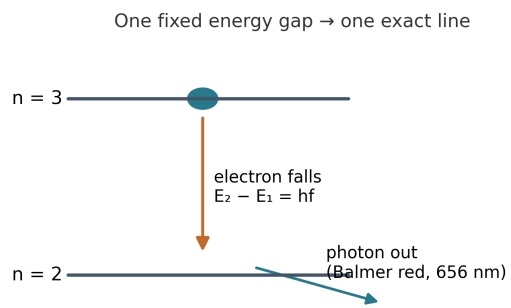
Electron configurations

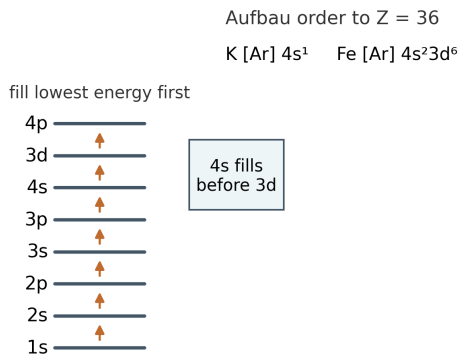
What would explain this observation?

- A hydrogen discharge tube glows, and a prism splits the light into a few exact coloured lines – not a continuous rainbow. Why only those colours?
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

Build the model

- An electron in an atom can only occupy fixed **energy levels** . When it falls from a higher level to a lower one, it emits one photon whose energy equals the gap: $E_2 - E_1 = hf$. A line **emission spectrum** is the set of these exact photon energies, so each element shows its own pattern of lines.
- Electrons fill the levels in a fixed order from lowest energy: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p. An **orbital** holds at most two electrons with opposite spins. The electron configuration lists the occupied sublevels, for example iron: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$, written compactly as [Ar] $4s^2\ 3d^6$.
- energy level: A fixed energy an electron may have in an atom; orbital: A region holding at most two electrons with opposite spins; emission spectrum: The exact set of light frequencies an element emits.





Choose evidence that can test it

- The emission lines of hydrogen fall at exact frequencies predicted by the level gaps. If electrons could have any energy, the spectrum would be continuous – the observed separate lines are the evidence for fixed levels.
- The first ionisation energies of successive elements rise in steps and fall at the start of each new shell, matching the order in which sublevels fill. Compare a measured spectrum or ionisation pattern with the configuration model before accepting an explanation.

Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: the red Balmer line of hydrogen has wavelength $\lambda = 656$ nm $= 656 \times 10^{-9}$ m; $c = 3.00 \times 10^8$ m/s and $h = 6.63 \times 10^{-34}$ J s. The photon energy equals the level gap: $E = hf$ and $f = c/\lambda$, so $E = hc/\lambda$. Substitution: $E = (6.63 \times 10^{-34} \times 3.00 \times 10^8)/(656 \times 10^{-9}) = 3.03 \times 10^{-19}$ J. This is the energy gap between the n = 3 and n = 2 levels.

Example:

The ultraviolet line of hydrogen has $\lambda = 122$ nm. Find the photon energy using the same sequence: known quantities → model → relation → substitution → unit and interpretation. (Answer: $E = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / (122 \times 10^{-9}) = 1.63 \times 10^{-18}$ J – about five times the red line's energy, because it spans the larger gap down to n = 1.)

■ Check the conclusion and its limits

- The filling order 4s before 3d is an empirical energy order for NEUTRAL atoms; when atoms lose electrons to form ions, the 4s electrons leave first (iron forms Fe^{2+} as [Ar] $3d^6$, not [Ar] $4s^2$ $3d^4$). The simple order also has noted exceptions such as chromium [Ar] $4s^1$ $3d^5$.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Electrons in an atom can occupy any energy between the shells. This claim is false: the separate lines of an emission spectrum appear only because electrons fall between fixed energy levels; a continuum of allowed energies would give a continuous spectrum, which is not observed.

Key:

Electron configurations: electrons occupy fixed energy levels, and the photon energy of each emission line equals the gap between two levels, $E = hc/\lambda$. Sublevels fill in the order 1s 2s 2p 3s 3p 4s 3d 4p, with at most two opposite-spin electrons per orbital.