Structure of the atom

International Baccalaureate · IB Diploma · Physics · SL

Scope and prerequisites

This handout covers selected SL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

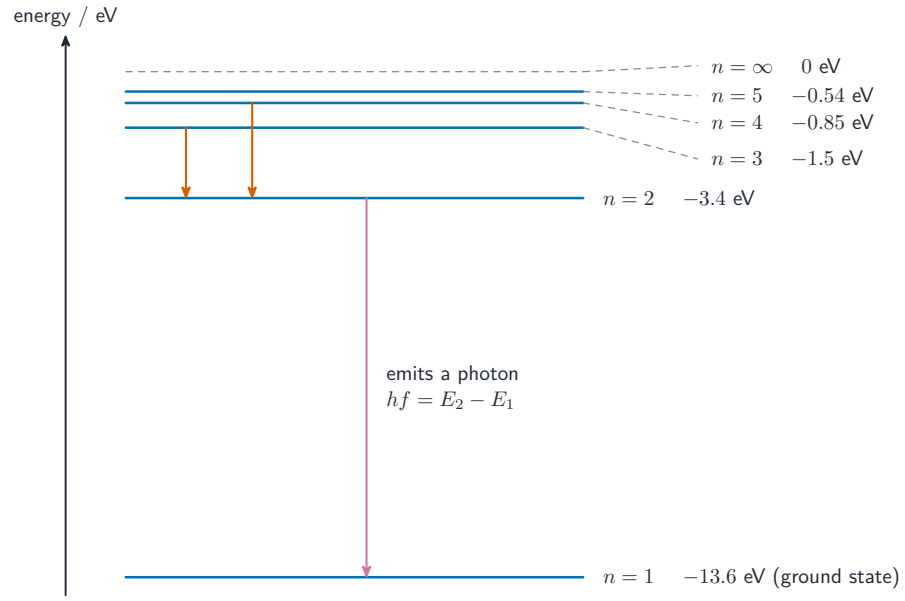
Atomic models and line spectra

What would explain this observation?

- An excited gas produces separate coloured lines rather than every wavelength. The pattern is evidence for discrete atomic energy differences.

Build the model

- Atoms have a small positive nucleus and electrons.
- Emission and absorption spectra arise from transitions between discrete **energy levels**.
- A photon energy equals the level difference and obeys E = hf.
- **emission spectrum** : Wavelength pattern of radiation emitted by a source.
- energy level : An allowed energy state in a model.



A downward transition emits one photon whose energy equals the level difference: hf = $E_2 - E_1$

Choose evidence that can test it

- An emitted photon corresponds to a transition to a lower energy level.
- Absorption requires a compatible energy difference.
- Rutherford scattering supported a small dense nucleus, but that experiment alone did not establish the complete quantum model.

In the lab: Read a labelled energy-level diagram before calculating. Keep joules and electronvolts distinct and use the given constants. Compare attributed spectra at a common wavelength scale and avoid looking at unsafe light sources.

Work from known quantities

- Known: energy levels are −6.0 and −2.0 eV.
- A downward transition releases 4.0 eV = 6.4×10^{-19} J using 1 eV = 1.6×10^{-19} J.
- With h = 6.4×10^{-34} J s for this rounded exercise, frequency is 1.0×10^{15} Hz.

Your turn: Levels are −7.0 and −2.0 eV. Find the energy emitted in the downward transition.

■ Check the conclusion and its limits

- Negative bound-state energies are relative to a chosen zero; they do not mean a negative photon energy is emitted.
- A larger downward energy difference gives higher frequency.

Not true: A negative bound-state energy means an emitted photon has negative energy. Level energies are measured relative to a chosen zero (a free electron at rest), so bound states are negative. The photon energy is the positive DIFFERENCE between levels - differences of negative numbers are positive.

Key:

- Atoms have a small positive nucleus and electrons.
- An emitted photon corresponds to a transition to a lower energy level.
- Watch for: negative bound-state energies are relative to a chosen zero; they do not mean a negative photon energy is emitted.

■ Write from a photon energy of 6 electronvolts

- Levels are minus 9.0 and minus 3.0 electronvolts.
- Find the photon energy of the downward transition. A negative level does not make the photon energy negative.

■ Write from an ionisation energy read

- An energy level sits at -5.0 eV.
- Ionisation needs $+5.0$ eV $= 8.0 \times 10^{-19}$ J – the ground-state binding energy read backwards.

■ Write from a three-level count

- Levels at -5, -3 and -1 eV.
- Transitions of 2, 4 and 2 eV – three transitions but only TWO distinct photon energies: count transitions, then count distinct lines.