

Atomic energy levels and line spectra

Physics grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

The marking notes show where each mark is earned. Award method marks even when the final number is wrong, and accept answers that are correct to the given significant figures and within the rounding stated.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB E.1

Question 1 The electronvolt (2 marks)

- a. One electronvolt is the energy gained by one electron when it is accelerated through a potential difference of 1 volt.
- b. $E = 2.5 \times 1.60 \times 10^{-19} = \mathbf{4.0 \times 10^{-19} \text{ J}}$.

Marking: 1 mark for the definition with electron and 1 V; 1 mark for the correct result with unit.

Question 2 Reading a level diagram (3 marks)

- a. $\Delta E = -1.6 - (-3.6) = \mathbf{2.0 \text{ eV}}$.
- b. $\lambda = 1240 / 2.0 = \mathbf{620 \text{ nm}}$.
- c. $\Delta E = -3.6 - (-8.4) = \mathbf{4.8 \text{ eV}}$; $\lambda = 1240 / 4.8 = 258 \text{ nm}$, which is below 400 nm, so the photon is not visible (ultraviolet).

Marking: 1 mark each; allow the visibility mark for a wavelength comparison with 400 to 700 nm.

Question 3 Discrete emission (2 marks)

The electrons in the atom can only have certain discrete energies (energy levels). When an electron falls between two levels, the photon energy equals the gap, so only particular photon energies, and therefore wavelengths, are possible.

Marking: 1 mark for discrete levels; 1 mark for photon energy equal to the difference between two levels.

Question 4 Dark lines in starlight (3 marks)

Light from the hot interior is nearly continuous. Atoms in the cooler atmosphere absorb photons whose energies match gaps between their levels, so those wavelengths are missing and appear as dark lines. Each element has its own pattern of gaps, so matching the dark lines with the known line pattern of an element shows that the element is present.

Marking: 1 mark for continuous source; 1 mark for absorption of photons that match level gaps; 1 mark for matching with laboratory patterns of each element.

Question 5 Hydrogen $n = 5$ to $n = 2$ (3 marks)

- a. $\Delta E = -0.54 - (-3.40) = \mathbf{2.86 \text{ eV}}$.
- b. $\lambda = 1240 / 2.86 = \mathbf{434 \text{ nm}}$.
- c. Violet light, in the visible region.

Marking: 1 mark for each part; accept 433 to 434 nm.

Question 6 Electron collision (2 marks)

The electron has less energy (9.0 eV) than the smallest gap (10.2 eV), so it cannot excite the atom. The collision is elastic and the atom stays in the ground state; the electron keeps almost all of its kinetic energy.

Marking: 1 mark for the comparison of 9.0 eV with 10.2 eV; 1 mark for the conclusion that no excitation occurs.

Question 7 A 100 nm photon (3 marks)

- a. $E = 1240 / 100 = \mathbf{12.4 \text{ eV}}$.
- b. The gaps from the ground state are 10.2 eV, 12.09 eV and 12.75 eV, and the ionisation energy is 13.6 eV. 12.4 eV matches none of them and is below 13.6 eV, so the photon **cannot be absorbed**.

Marking: 1 mark for 12.4 eV; 1 mark for comparing with the gaps; 1 mark for the conclusion.

Question 8 Photons from a laser pointer (2 marks)

- a. $E = hc / \lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (532 \times 10^{-9}) = \mathbf{3.74 \times 10^{-19} \text{ J}}$.
- b. $N = P / E = 5.0 \times 10^{-3} / 3.74 \times 10^{-19} = \mathbf{1.34 \times 10^{16} \text{ s}^{-1}}$.

Marking: 1 mark each, with unit.