

Atomic energy levels and line spectra

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems train you to move between electronvolts and joules, to read level diagrams and to turn a transition into a photon energy and a wavelength. They progress from definitions to multi-step data analysis with hydrogen, sodium and fluorescent lamps. They suit A Level, IB Physics SL and HL, CBSE class 12 and WAEC senior students. Use $h = 6.63 \times 10^{-34} \text{ J s}$, $c = 3.00 \times 10^8 \text{ m/s}$ and $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$ unless the problem says otherwise.

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

Problem 1 Energy levels in words (easy)

Aarav in Pune is revising atomic structure.

1. State what is meant by an energy level in an atom.
2. Explain why an electron bound in an atom cannot have an energy between two levels.
3. State the meaning of the ground state.

Problem 2 Electronvolts to joules (easy)

Chiamaka in Lagos converts an energy to SI units. Calculate the energy of 4.5 eV in joules. Use $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$.

Problem 3 Joules to electronvolts (easy)

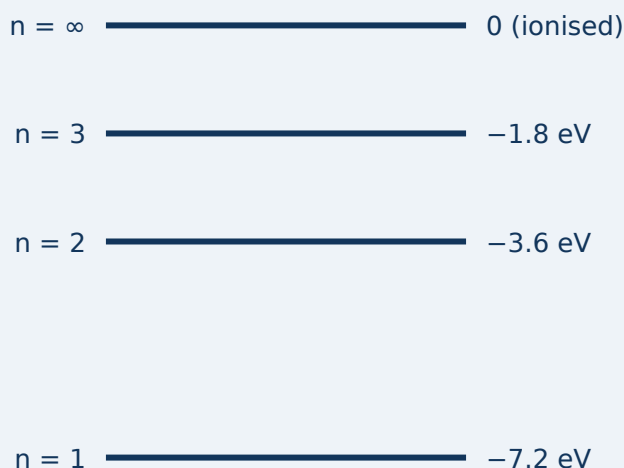
A photon has energy $3.84 \times 10^{-19} \text{ J}$. Calculate its energy in eV.

Problem 4 Wavelength of a 2.0 eV photon (easy)

Calculate the wavelength of a photon of energy 2.0 eV, and state whether it is visible. Use $\lambda \text{ (nm)} = 1240 / E \text{ (eV)}$.

Problem 5 Reading a level diagram (easy)

The diagram shows the levels of a model atom.



Levels of the model atom.

1. State the ionisation energy.
2. State how many different photon energies the atom can emit when an electron starts at $n = 3$ and falls to the ground state by any route.
3. Calculate the three photon energies and wavelengths, and state which one is visible.

Problem 6 The $n = 4$ to $n = 2$ line (medium)

Emma in Leeds studies the blue-green line of hydrogen. Calculate the wavelength of the photon emitted when an electron falls from $n = 4$ (-0.85 eV) to $n = 2$ (-3.40 eV).

Problem 7 Ionising from $n = 2$ (medium)

A hydrogen atom is in the $n = 2$ level. Calculate the longest wavelength of a photon that can ionise it, and state which region of the spectrum it lies in.

Problem 8 Photons from a sodium lamp (medium)

Kofi in Accra reads that a sodium street lamp radiates 12 W as yellow light of wavelength 589 nm. Use $h = 6.63 \times 10^{-34}$ J s and $c = 3.00 \times 10^8$ m/s.

1. Calculate the energy of one photon in J and in eV.
2. Calculate the number of photons emitted each second.

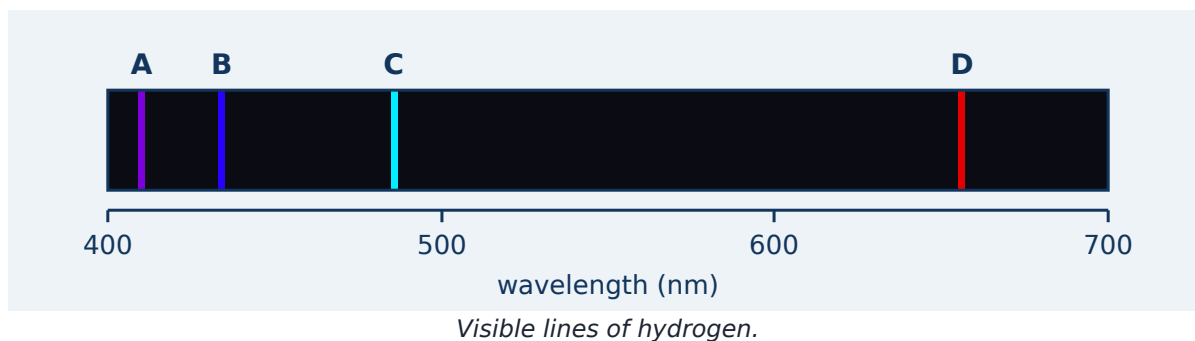
Problem 9 Frequency of red hydrogen light (medium)

The red line of hydrogen has wavelength 656 nm. Calculate its frequency. Use $c = 3.00 \times 10^8$ m/s.

Problem 10 Identifying the line (medium)

Mei in Singapore photographs the visible spectrum of hydrogen. The strip shows four bright

lines.



1. State which line, A to D, comes from the photon of highest energy.
2. Calculate the energy of that photon in eV.
3. Hydrogen level $n = 6$ is at -0.38 eV and $n = 2$ is at -3.40 eV. Show that this line comes from the transition $n = 6 \rightarrow n = 2$.

Problem 11 Dark lines from cool gas (medium)

Explain why a cool gas placed between a white lamp and a spectroscope produces dark lines at the same wavelengths at which the hot gas gives bright lines.

Problem 12 Filament lamp or neon sign (medium)

Compare the light from a filament lamp with the light from a neon sign when each is viewed through a spectroscope.

Problem 13 Spot the errors (medium)

Diego in Texas wrote: "An electron in the $n = 3$ level of hydrogen has energy $+1.51$ eV, so $13.6 - 1.51$ eV is needed to ionise the atom from there." Identify and correct the two mistakes.

Problem 14 An electron beam in hydrogen (medium)

A beam of electrons, each of kinetic energy 11.0 eV, passes through hydrogen gas in the ground state ($n = 1$ at -13.6 eV; $n = 2$ at -3.40 eV; $n = 3$ at -1.51 eV).

1. Show that a collision can excite an atom to $n = 2$ but not to $n = 3$.
2. Calculate the kinetic energy of an electron after it has excited an atom to $n = 2$.
3. Calculate the wavelength of the photon emitted when that atom returns to the ground state.

Problem 15 Routes down from $n = 4$ (medium)

Hydrogen levels: $n = 1$ at -13.6 eV, $n = 2$ at -3.40 eV, $n = 3$ at -1.51 eV, $n = 4$ at -0.85 eV.

1. Count the different transitions possible for atoms with an electron in $n = 4$, using all

routes down to the ground state.

2. Calculate the wavelength of the shortest-wavelength photon that can be emitted.
3. Calculate the wavelength of the longest-wavelength photon and state its region.

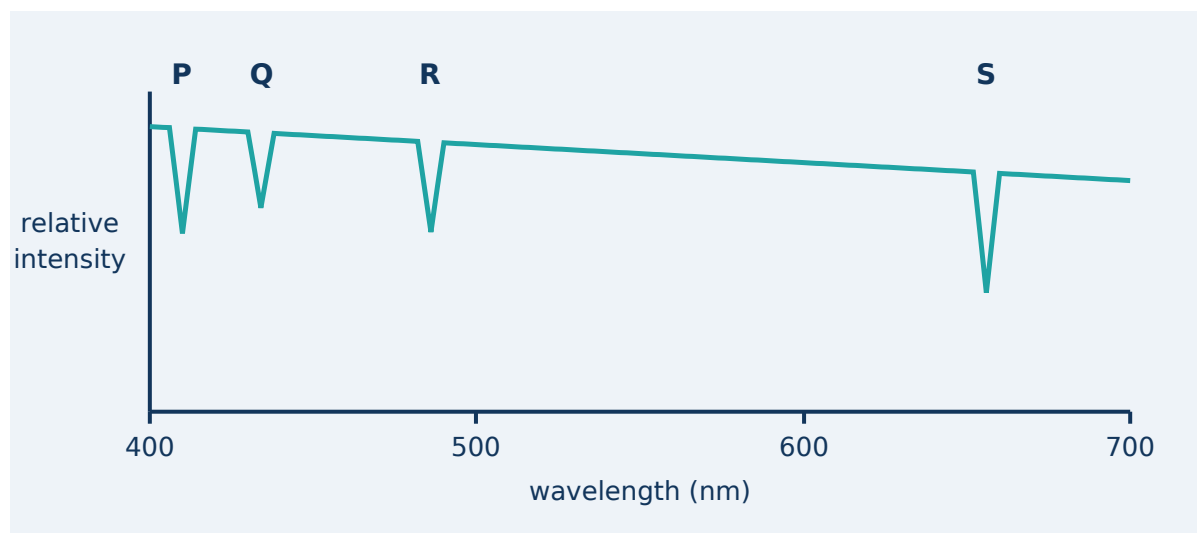
Problem 16 Series limit (hard)

The lines of hydrogen that end on $n = 2$ get closer together towards a series limit at 365 nm.

1. Calculate the photon energy at the series limit.
2. Explain what this energy represents and deduce the energy of the $n = 2$ level.
3. Using $E = -A / n^2$, find A and the ground-state energy.

Problem 17 Reading a stellar spectrum (hard)

Wanjiru in Nairobi studies the spectrum of a star. The graph shows four narrow dips. They are caused by hydrogen atoms in the star's atmosphere that start in the $n = 2$ level (-3.40 eV).



Intensity of starlight against wavelength.

1. Explain how the dips form.
2. Calculate the photon energy absorbed at dip Q (434 nm).
3. Determine the level number n to which the electron is raised at dip Q.

Problem 18 Levels from three lines (hard)

A vapour emits only three lines, at 620 nm, 413 nm and 248 nm. They come from transitions between three levels. The ground state is at -9.0 eV and the 620 nm line comes from the smallest gap.

1. Calculate the energy of each photon.
2. Deduce the energies of the other two levels.
3. Explain how the three energies confirm that only three levels are involved.

Problem 19 Excitation by photons of one energy (hard)

A beam of photons, each of energy 12.09 eV, is directed at hydrogen atoms in the ground state (-13.6 eV). Hydrogen levels: -3.40 eV ($n = 2$), -1.51 eV ($n = 3$).

1. Show that the atoms can absorb these photons.
2. List the photon wavelengths that the gas can then emit.
3. State which of those photons are visible.

Problem 20 Fluorescent coating (hard)

Bilal in Lahore learns that a fluorescent tube produces ultraviolet photons of wavelength 254 nm from excited mercury atoms. A phosphor coating absorbs each one and emits a photon of wavelength 540 nm.

1. Calculate the energy of each type of photon in eV.
2. Calculate the energy lost to the coating per photon.
3. Calculate the percentage of the energy of each ultraviolet photon that is emitted as visible light.