2023 Ph H2 Q10

Section: Particles and Waves

Topic: Atomic Spectra (Bohr Model)

Summary of Question:

Bohr model features; how line emission spectra are produced and why some lines are brighter; use given hydrogen energy levels to count possible emission lines and to calculate photon frequency, identify a blue-green wavelength, and find its redshifted wavelength from a receding galaxy.

(a) One other feature of the Bohr model

Answer: The atom has a central positively charged nucleus.

(b)(i) Explain how a line emission spectrum is produced

Electrons excited to higher energy levels can drop to lower levels; when they do this they emit photons. Different transitions produce photons of specific energies (frequencies), giving discrete spectral lines.

(b)(ii) Explain why some lines appear brighter than others

More electrons per second make those particular transitions, so more photons (of that energy) are emitted per second, leading to brighter lines.

(c)(i) Number of possible emission lines

There are 5 energy levels shown. Number of distinct downward transitions = $n(n-1)/2 = 5\times4/2 = 10$.

(c)(ii)(A) Frequency for the $E_4 \to E_1$ transition

Energy difference: $\Delta E = E_1 - E_4 = (-5.45\times10^{-19}) - (-0.871\times10^{-19}) = 4.579\times10^{-19}$ J

Use $E = hf \Rightarrow f = \Delta E/h = (4.579\times10^{-19})/(6.63\times10^{-34}) = 6.91\times10^{14}$ Hz

(c)(ii)(B) Wavelength of the blue-green spectral line

Answer: 486 nm

(c)(ii)(C) Observed wavelength for $v = 4.52\times10^{6}$ m s^{-1}

Redshift $z = v/c = (4.52\times10^{6})/(3.00\times10^{8}) = 0.01507$

$\lambda_{obs} = \lambda_{rest}(1 + z) = 486 \text{ nm} \times 1.01507 = 4.93\times10^{-7}$ m (≈ 493 nm)

Final Answers

(a) Central positively charged nucleus (any one valid Bohr feature).

(b)(i) Electrons drop to lower levels and emit photons → discrete spectral lines.

(b)(ii) Brighter lines: more electrons per second make those transitions (more photons).

(c)(i) 10 lines

(c)(ii)(A) 6.91×10^{14} Hz

(c)(ii)(B) 486 nm

(c)(ii)(C) 4.93×10^{-7} m (≈ 493 nm)

Revision Tips

- Use $\Delta E = hf$ and $E = -13.6\ \text{eV}/n^2$ (for hydrogen) to reason about transitions.

- Intensity of a spectral line is about the rate of that transition, not photon energy.

- For small redshifts ($v \ll c$), $z \approx v/c$ and $\lambda_{obs} \approx \lambda_{rest}(1+z)$.