2018 Ph H2 Q10

Section: Particles and Waves

Topic: Atomic spectra, Bohr model, redshift

(a) State two features of the Bohr model of the atom.
(b) From hydrogen energy levels, calculate frequency of photon for transition $E_3 \rightarrow E_1$.
(c) A hydrogen line shifts from 656 nm in the lab to 661 nm in a distant galaxy. Calculate the galaxy's recessional velocity.

Worked solution

(a)
Two features of Bohr model:
• Electrons orbit the nucleus in discrete, quantised energy levels.
• Energy is absorbed or emitted only when electrons change levels, in photons of energy hf.

Answer: Quantised orbits, photons emitted/absorbed in transitions

(b)
Energy difference $\Delta E = E_3 - E_1$.
$= (-2.42 \times 10^{-19}) - (-21.8 \times 10^{-19}) = 1.94\text{e-}18$ J.
Frequency $f = \Delta E/h = 1.94\text{e-}18/6.63\text{e-}34 = 2.92\text{e+}15$ Hz.

Answer: 2.9×10^{15} Hz

(c)
Recessional velocity from redshift:
$v/c = (\lambda_{obs} - \lambda_{lab})/\lambda_{lab}$.
$= (661 - 656)/656 = 0.00762$.
$v = 2.29e+06\ m\ s^{-1}$.

Answer: $2.3 \times 10^6\ m\ s^{-1}$

Final answers

(a) Bohr model: electrons in quantised levels; photons absorbed/emitted in transitions

(b) $f = 2.9 \times 10^{15}$ Hz

(c) $v = 2.3 \times 10^6\ m\ s^{-1}$

Revision tips

- Bohr model: electrons occupy fixed energy levels.
- Energy change $\Delta E = hf$.
- Use given energy levels directly to find photon frequencies.
- Redshift: $(\Delta\lambda/\lambda) = v/c$ for small z.
- Greater redshift → higher recessional velocity → evidence for expanding universe.