Unit 23 · Quantization of Energy

HARDER PRACTICE QUESTIONS

Full marks 32

Write your answers on separate paper. Show your working. Take $h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m/s, $e = 1.6 \times 10^{-19}$ C, the mass of an electron 9.1×10^{-31} kg and Rydberg's constant 1.097×10^{7} m^{-1}.

1 Spot the error [3]

Find the mistake in the working and correct it.

Asked for the wavelength of the line given out when hydrogen's electron falls from n = 4 to n = 1, Sudip wrote:

"$\frac{1}{\lambda} = R\left(\frac{1}{1} - \frac{1}{4}\right) = 1.097 \times 10^{7} \times 0.75$, so $\lambda = 1.22 \times 10^{-7}$ m."

2 Read the data [4]

Gopal shone X-rays of wavelength 1.54 Å on a crystal and found reflections at three glancing angles.

Order n	1	2	3
θ	15.8°	33.1°	55.0°

i. Find the spacing of the planes from each reading.
ii. What is the best value?
iii. Show that there is no fourth order.

3 Predict, then explain [3]

Write your prediction first, then explain it.

An X-ray tube is running. Predict what happens to i. the shortest wavelength of its X-rays and ii. the number of X-ray photons each second, when first the voltage across it is doubled, and then, instead, the filament current is raised. Then explain.

4 Show that [3]

Show that the wavelength of the first line of hydrogen's Lyman series is 5/27 of that of the first line of its Balmer series. Is the Lyman line longer or shorter?

5 Estimate it [3]

An electron in an atom is somewhere in a space about 1 Å across. Using $\Delta x\,\Delta p \geq h/2\pi$, estimate the least uncertainty in its speed. Compare it with its speed in Bohr's first orbit, about 2.2×10^{6} m/s. What does this say about Bohr's sharp orbits?

6 Which explanation fits? [2]

The spectrum of sunlight has thin dark lines at exactly the wavelengths of hydrogen's bright lines. Explanation A: the Sun has no hydrogen. Explanation B: cooler hydrogen in the Sun's outer layers absorbs those wavelengths from the light behind it. Which fits? Why?

7 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Sabina wrote: "In Bohr's model the electron gives out light all the time as it goes round. The shortest wavelength of an X-ray tube depends on the metal of its target. At the same speed, a proton has a longer de Broglie wavelength than an electron, because it is heavier."

8 Work backwards [3]

Hydrogen gives out a line of wavelength 1282 nm. Find the photon's energy in eV, and find the jump that gives it, using $E_n = -13.6/n^2$ eV. Which series is it in?

9 Compare [4]

An X-ray photon and an electron both have a wavelength of 0.10 nm.

i. Find their momentum (the same for both).
ii. Find the photon's energy in eV.
iii. Find the electron's kinetic energy in eV.
iv. Which is gentler on a delicate sample? Why?

10 What if? [2]

What if the electron in a hydrogen atom were twice as heavy, its charge unchanged? Using $r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$ and $E_n = -\frac{m e^4}{8 \varepsilon_0{}^2 n^2 h^2}$, say what would happen to the atom's size and its ionization energy.

11 Make your own [2]

Write a problem about an X-ray tube whose answer is "the shortest wavelength is 0.25 Å". Solve it to show it works.