

Atoms — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Atomic Models (Thomson to Rutherford)

1. Describe Thomson's model of the atom and state its limitations.
2. State two conclusions drawn from Rutherford's alpha-particle scattering experiment.
3. State the main drawback of Rutherford's model.

Bohr's Model of the Hydrogen Atom

1. State the postulates of Bohr's model of the hydrogen atom.
2. The radius of the first Bohr orbit of hydrogen is $0.53 \text{ \AA}$. Find the radius of the third orbit.
3. Derive the expression for the radius of the n th Bohr orbit.

Hydrogen Line Spectra

1. Name the different series of the hydrogen spectrum and their regions.
2. Calculate the wavelength of the first line of the Balmer series of hydrogen.
3. Derive the expression for the wave number of the hydrogen spectral lines.

Energy of the Electron and Ionisation

1. Write the value of the ground-state energy of the hydrogen atom.
2. Calculate the energy required to excite a hydrogen atom from $n = 1$ to $n = 2$.
3. Find the ionisation energy of the hydrogen atom.

de Broglie Wavelength of the Electron

1. State the de Broglie relation for a Bohr orbit.
2. Show that the de Broglie wavelength of an electron in the n th orbit is proportional to n .
3. Calculate the de Broglie wavelength of an electron in the ground state of hydrogen.

Part B — Integrated problems (multi-topic)

1. The radius of the first Bohr orbit of hydrogen is $0.53 \text{ \AA}$. Find the radius and the energy of the electron in the third orbit.
2. Calculate the wavelength of the first line of the Lyman series of the hydrogen atom. ($R = 1.097 \times 10^7 \text{ m}^{-1}$)
3. Calculate the energy required to excite a hydrogen atom from the ground state to the first excited state and the corresponding wavelength of radiation absorbed.

4. Find the energy required to ionise a hydrogen atom from its first excited state ($n = 2$).
5. Calculate the de Broglie wavelength of an electron in the ground state of the hydrogen atom.

Answer Key

Atomic Models (Thomson to Rutherford)

Thomson: positive sphere with embedded electrons. Rutherford: alpha scattering showed a tiny, dense, positively charged nucleus with electrons outside; could not explain atomic stability.

Bohr's Model of the Hydrogen Atom

Postulates: stationary orbits with no radiation; angular momentum = $nh/2\pi$; radiation emitted only on transitions. $r_n = 0.53 n^2 \text{ \AA}$; for $n = 3$, $r = 4.77 \text{ \AA}$.

Hydrogen Line Spectra

Lyman (UV, $n \rightarrow 1$), Balmer (visible, $n \rightarrow 2$), Paschen (IR, $n \rightarrow 3$), Brackett, Pfund. Wave number = $R(1/n_1^2 - 1/n_2^2)$. First Balmer line $\approx 656 \text{ nm}$.

Energy of the Electron and Ionisation

$E_n = -13.6/n^2 \text{ eV}$. Ground state -13.6 eV , $n=2$ -3.4 eV , $n=3$ -1.51 eV . Ionisation energy from ground state = 13.6 eV ; ionisation potential = 13.6 V .

de Broglie Wavelength of the Electron

$2\pi r = n\lambda$ gives the quantisation of angular momentum. For the ground state of hydrogen, $\lambda \approx 3.32 \times 10^{-10} \text{ m}$.

Integrated problems

1: $r_3 = 0.53 \times 9 = 4.77 \text{ \AA}$; $E_3 = -13.6/9 \approx -1.51 \text{ eV}$. 2: $1/\lambda = R(1 - 1/4)$ $\lambda \approx 121.5 \text{ nm}$ (for $n=2 \rightarrow 1$; first line $n=2 \rightarrow 1$). 3: $\Delta E = 13.6 - 3.4 = 10.2 \text{ eV}$; $\lambda = 1240/10.2 \approx 121.6 \text{ nm}$. 4: $E_2 = -3.4 \text{ eV}$, so ionisation from $n = 2$ needs 3.4 eV . 5: $\lambda = 2\pi r_1 \approx 3.32 \times 10^{-10} \text{ m}$.