INDIAN SCHOOL AL WADI AL KABIR		
Class: XII	**DEPARTMENT OF SCIENCE: 2026-27** **SUBJECT: PHYSICS**	**DATE: 08/11/2026**
WORKSHEET NO: 12 (WITH ANSWERS)	**CHAPTER: ATOMS**	**A4 FILE FORMAT** **(PORTFOLIO)**
CLASS & SEC:	**NAME OF THE STUDENT:**	**ROLL NO.**

OBJECTIVE TYPE QUESTIONS (1 MARK)

1) In Bohr's atomic model, if the atomic radius of the first orbit is r_o, then the radius of the fourth orbit is (SQP 2017)

   a) r_o
   b) $4r_o$
   c) $8r_o$
   d) $16r_o$

2) If the speed of an electron in the ground state of a hydrogen atom is v_1, the speed of the electron in the 3rd orbit (n = 3) will be: (CBSE 2024)

   a) $3\ v_1$
   b) $v_1 / 3$
   c) $9\ v_1$
   d) $v_1 / 9$

3) A hydrogen atom makes a transition n=5 to n=1 orbit. The wavelength of the photon emitted is λ. The wavelength of the photon emitted when it makes a transition from n=5 to n=2 orbit is: (OD 2023)

   a) 8/7 λ
   b) 16/7 λ
   c) 24/7 λ
   d) 32/7 λ

4) In Bohr's atomic model of the hydrogen atom, the product of the binding energy of the electron in n^{th} orbit and its radius in n^{th} orbit is
   (Foreign 2006)

   a) Independent of n

b) Proportional to n
c) Proportional to n^2
d) Inversely proportional to n

5) In which of the following systems will the radius of the first orbit be minimum? (Foreign 2014)
a) Hydrogen atom
b) Deuterium atom
c) Singly ionised helium
d) Doubly ionised lithium

6) Which of the triply ionised beryllium (Be^{+++}) has the same orbital radius as that of the ground state of hydrogen?

a) n=1
b) n=2
c) n=3
d) n=4

7) An alpha particle of energy 5.5 MeV approaches a gold nucleus (Z = 79) head-on. At the point of closest approach, the impact parameter b is: (CBSE 2026)

a) Maximum

b) Zero

c) Equal to the radius of the nucleus

d) Infinite

8) The total energy of an electron in an orbit of a hydrogen atom is -3.4 eV. Its kinetic energy (K) and potential energy (U) in this orbit are respectively: (CBSE 2026)

a) +3.4 eV, -6.8 eV

b) -3.4 eV, -3.4 eV

c) +6.8 eV, -3.4 eV

d) +3.4 eV, -3.4 eV

9) The ratio of the shortest wavelength in the Lyman series to the shortest wavelength in the Balmer series of the hydrogen atom spectrum is:

a) 1:2

b) 1:4

c) 1:9

d) 4:9

10) The de Broglie wavelength λ of an electron revolving in the 3rd Bohr orbit of a hydrogen atom is related to the radius r_3 of the orbit as: (CBSE 2025)

a) $2\pi r_3 = 3\lambda$
b) $\pi r_3 = 3\lambda$

c) $2\pi r_3 = \lambda/3$
d) $2\pi r_3 = 9\lambda$

ASSERTION AND REASONING TYPE OF QUESTIONS (1 MARK):

DIRECTIONS: In the following questions, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
a) Both A and R are true, and R is the correct explanation of A.
b) Both A and R are true, and R is not the correct explanation of A.
c) A is true, but R is false.
d) Both A and R are false

11) **Assertion (A):** According to classical electromagnetic theory, Rutherford's planetary model of the atom is inherently unstable.
Reason (R): An accelerating charge continuously emits electromagnetic radiation and loses energy, causing the electron to spiral into the nucleus.
12) **Assertion (A):** An alpha particle is moving towards a gold nucleus. The impact parameter is maximum for the scattering angle of 180°
Reason (R): The impact parameter in an alpha particle scattering experiment doesn't depend upon the atomic number of the target nucleus.
13) **Assertion (A):** The spectral lines of the hydrogen atom are discrete and sharp.
Reason (R): Energy levels of electrons in a hydrogen atom are quantised, and transitions take place between specific stationary orbits.

VERY SHORT ANSWER TYPE OF QUESTIONS: (2 MARKS)

14) Define 'impact parameter' in alpha-particle scattering. How does the angle of scattering depend on the magnitude of the impact parameter? Illustrate with a clean trajectory sketch. (CBSE 2026)

15) Calculate the shortest and longest wavelengths of light emitted in the Balmer series of the hydrogen spectrum. (Take Rydberg constant $R = 1.097 \times 10^7\ m^{-1}$). (CBSE 2025)

16) Using Bohr's formula for energy levels, calculate the wavelength of the photon emitted during a transition from n = 4 to n = 2 in a hydrogen atom. Identify the spectral series to which this line belongs.

17) A proton of energy 1.6 MeV approaches a gold nucleus (Z=79). Find the distance of closest approach.

SHORT ANSWER TYPE OF QUESTIONS (3 MARKS):

18) Use the Bohr model of the hydrogen atom to calculate the speed of the electron in the first excited state.

19) In a Geiger-Marsden experiment, an alpha particle of kinetic energy 5.5 MeV approaches a gold nucleus (Z = 79) head-on.
(a) Calculate the distance of closest approach r_0.
(b) What will be the value of r_0 if the 5.5 MeV alpha particle is replaced by a proton of the same kinetic energy? Explain the physical reason.

20) Draw a neat energy level diagram of the hydrogen atom up to n = 5, showing the Lyman and Balmer series transitions.
(a) Mark the transition corresponding to the maximum wavelength line in the Lyman series.
(b) Mark the transition corresponding to the series limit (minimum wavelength) in the Balmer series.
(c) State which regions of the electromagnetic spectrum these two lines belong to.

21) A beam of 12.5 eV electrons is used to bombard gaseous hydrogen at room temperature (ground state n = 1).
(a) Up to which energy level (n) can the hydrogen atoms be excited?
(b) Calculate the highest wavelength of radiation emitted when the excited hydrogen atoms return to lower states.
(c) How many total spectral lines can be observed in the emission spectrum?

LONG ANSWER TYPE OF QUESTIONS (5 MARKS):

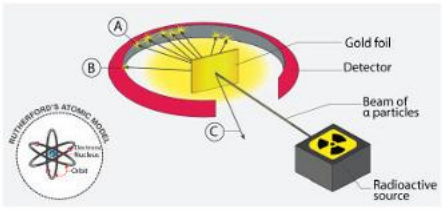
22) In a hydrogen atom, an electron undergoes transition from the second excited state to the first excited state and then to the ground state. Find out the ratio of the wavelengths of the emitted radiation in the two cases. (Foreign 2012)

23) Describe Rutherford's model of the atom developed based on his alpha scattering experiment.

24) (a) Explain why Bohr's model is strictly applicable only to single-electron (hydrogen-like) species like H, He^{+}, and Li^{2+}.
(b) A hydrogen atom initially in its ground state absorbs a photon and gets excited to the n = 4 state.
(i) Calculate the energy (in eV) and wavelength (in nm) of the absorbed photon.
(ii) Find the maximum and minimum frequency of the photons that can be emitted during the de-excitation process back to the ground state.
(iii) Calculate the orbital angular momentum of the electron in the n = 4 state in terms of $h/2\pi$.

CASE STUDY TYPE OF QUESTIONS (4 MARK):

25) In 1911, Geiger and Marsden (under the guidance of Ernest Rutherford) directed a beam of 5.5 MeV alpha particles from a radioactive source at a thin gold foil of thickness ~2.1×10^{-7} m. The scattered alpha particles were detected using a zinc sulphide (ZnS) screen coupled with a microscope. Observations revealed that over 99.8% of the alpha particles passed through undeflected, while about 1 in 8000 was deflected by more than 90°, and extremely few recoiled back at ~180°. From these observations, Rutherford deduced that almost the entire mass and total positive charge of the atom is concentrated in a tiny central volume called the nucleus, leaving most of the atomic volume empty.



i. Two alpha particles approach a gold nucleus with impact parameters $b_1 < b_2$. Which is correct?
a) The particle with b_1 suffers greater deflection
b) The particle with b_2 suffers greater deflection
c) Both suffer equal deflection

d) Deflection is independent of impact parameter

ii. If the gold foil were replaced by an aluminium foil of the same thickness, the number of alpha particles scattered through very large angles would most likely:
   a) Increase, because aluminium has more electrons
   b) Decrease, because aluminium nuclei have lower positive charge
   c) Remain exactly the same
   d) Become zero, as aluminium is lighter

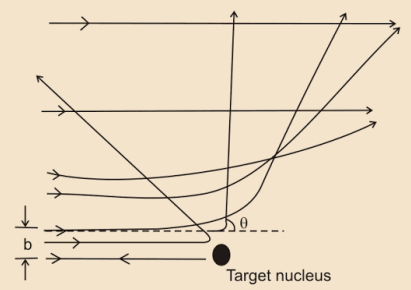
iii. An alpha particle passes very close to a gold nucleus but not head-on. Which statement best explains its trajectory?
   a) It is attracted by electrons and follows a circular path
   b) It experiences a repulsive force whose direction changes as it moves, producing a hyperbolic path
   c) It is absorbed by the nucleus and re-emitted
   d) It moves in a straight line because the nucleus is neutral

iv. If atoms had positive charge spread uniformly throughout their volume, as in Thomson's model, what would most likely happen to alpha particles?
   a) Nearly all would rebound backwards
   b) Very few would experience a force strong enough to deflect them through large angles
   c) All would be absorbed by the foil
   d) They would spiral around electrons

OR

If the kinetic energy of the alpha particles is doubled, the distance of closest approach for head-on collisions will:
   a) Become double
   b) Become half
   c) Become four times
   d) Remain unchanged

ANSWER KEY	
1	d)$16r_o$
2	b)$v_1 / 3$
3	d)$32/7\ \lambda$
4	a)Independent of n
5	d)Doubly ionized lithium
6	b)n=2
7	b)Zero
8	a)+3.4 eV, -6.8 eV
9	b) 1:4
10	a)$2\pi r_3 = 3\lambda$

11	a)Both A and R are true, and R is the correct explanation of A.
12	d)Both A and R are false
13	a)Both A and R are true, and R is the correct explanation of A.
14	**Definition:** The impact parameter b is the perpendicular distance between the initial direction of motion of an alpha particle and the centre of the target nucleus. **Dependence on scattering angle:** A smaller impact parameter means the alpha particle approaches closer to the positively charged nucleus. The Coulomb repulsive force is therefore stronger, so the scattering angle becomes larger. • For b=0, the collision is head-on, and the alpha particle rebounds through nearly 180 °. • For large b, the particle passes far from the nucleus and is deflected only slightly. Dependence: Trajectory depends inversely on b. Small b ⇒ large scattering angle θ (head-on collision b=0, θ=180°); large b ⇒ small deflection (θ ≈ 0°). 
15	Balmer Series formula: $1/\lambda = R\,(1/2^2 - 1/n_2^2)$, where $n_2 = 3, 4, 5, \ldots$ **Shortest wavelength:** transition from $n_i = \infty$ to $n_f = 2$. $$\frac{1}{\lambda_{\min}} = R\left(\frac{1}{4} - 0\right) = \frac{R}{4}$$ $$\lambda_{\min} = \frac{4}{R} = \frac{4}{1.097 \times 10^7} = 3.65 \times 10^{-7}\ \text{m}$$ $$\boxed{\lambda_{\min} = 365\ \text{nm}}$$

Longest wavelength: transition from $n_i = 3$ to $n_f = 2$.

$$\frac{1}{\lambda_{\max}} = R\left(\frac{1}{4} - \frac{1}{9}\right) = R\left(\frac{9-4}{36}\right) = \frac{5R}{36}$$

$$\lambda_{\max} = \frac{36}{5R} = \frac{36}{5 \times 1.097 \times 10^7} = 6.56 \times 10^{-7}\ \text{m}$$

$$\boxed{\lambda_{\max} = 656\ \text{nm}}$$

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$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R\left(\frac{1}{4} - \frac{1}{16}\right) = \frac{3R}{16}$$

$$\lambda = \frac{16}{3R} = \frac{16}{3 \times 1.097 \times 10^7} = 4.86 \times 10^{-7}\ \text{m}$$

$$\boxed{\lambda = 486\ \text{nm}}$$

Since the transition ends at n=2, it belongs to the **Balmer series** and lies in the **visible region**.

17

$$K = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_0}$$

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{K}$$

$$Z = 79, \qquad K = 1.6\ \text{MeV} = 1.6 \times 10^6 \times 1.6 \times 10^{-19}\ \text{J}$$

$$K = 2.56 \times 10^{-13}\ \text{J}$$

$$r_0 = \frac{9 \times 10^9 \times 79 \times (1.6 \times 10^{-19})^2}{2.56 \times 10^{-13}}$$

$$\boxed{r_0 = 7.1 \times 10^{-14}\ \text{m}}$$

18

$$v = k\frac{2\pi e^2}{nh}$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{2\pi e^2}{nh} = \frac{e^2}{2\varepsilon_0 h}\cdot\frac{1}{n}$$

$$v = \frac{e^2}{2\varepsilon_0 h}\cdot\frac{1}{n}$$

$$= \frac{(1.6\times10^{-19})^2}{2\times8.85\times10^{-12}\times6.63\times10^{-34}}\left(\frac{1}{n}\right)$$

$$= \frac{2.18\times10^6}{n}\text{m/s}$$

For $n = 2$,

$$v_2 = \frac{2.18\times10^6}{2} = 1.09\times10^6\text{m/s}$$

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(a) Alpha particle, $K = 5.5$ MeV

For an alpha particle, charge $= 2e$. At closest approach:

$$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0}$$

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{K}$$

$$Z = 79, \qquad K = 5.5\text{ MeV} = 8.8\times10^{-13}\text{ J}$$

$$r_0 = \frac{9\times10^9\times2\times79\times(1.6\times10^{-19})^2}{8.8\times10^{-13}}$$

$$\boxed{r_0 = 4.14\times10^{-14}\text{ m}}$$

(b) Proton of the same kinetic energy

For a proton, charge $= e$, not $2e$.

$$r_0' = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{K}$$

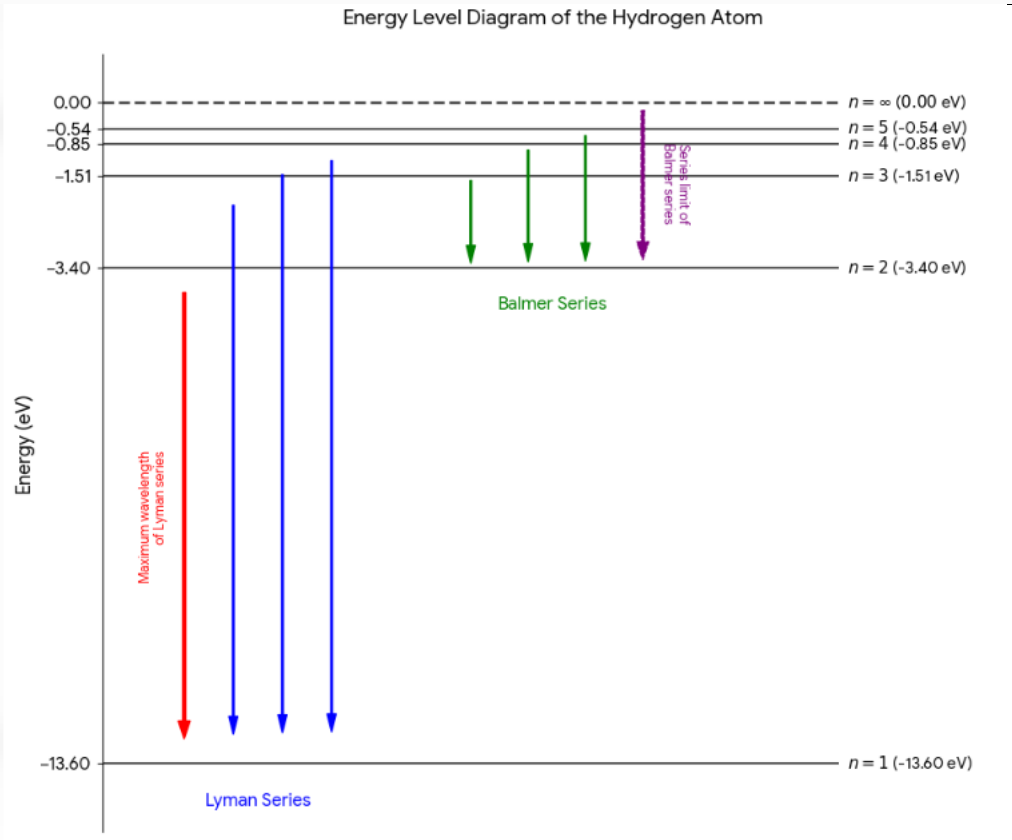
Since the alpha particle has charge $2e$, while the proton has charge e, the proton experiences half the Coulomb repulsion at the same separation.

$$r_0' = \frac{r_0}{2}$$

$$\boxed{r_0' = 2.07 \times 10^{-14}\ \text{m}}$$

Physical reason: The alpha particle carries charge $+2e$, whereas the proton carries charge $+e$. Therefore, for the same kinetic energy, the proton can approach closer to the gold nucleus.

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(c) Spectral regions

- Maximum-wavelength Lyman line, $2 \rightarrow 1$: **ultraviolet region**
- Balmer series limit, $\infty \rightarrow 2$: **ultraviolet region**

21

$$E_n = -\frac{13.6}{n^2}\ \text{eV}$$

(a) Highest excited level

Energy required to excite hydrogen from $n = 1$ to n:

$$\Delta E = 13.6\left(1 - \frac{1}{n^2}\right)\ \text{eV}$$

For $n = 3$:

$$\Delta E = 13.6\left(1 - \frac{1}{9}\right) = 13.6 \times \frac{8}{9} = 12.09\ \text{eV}$$

Since $12.09\ \text{eV} < 12.5\ \text{eV}$, excitation to $n = 3$ is possible.

For $n = 4$:

$$\Delta E = 13.6\left(1 - \frac{1}{16}\right) = 12.75\ \text{eV}$$

Since $12.75\ \text{eV} > 12.5\ \text{eV}$, excitation to $n = 4$ is not possible.

$$\boxed{n_{\max} = 3}$$

(b) Highest wavelength emitted

The highest wavelength corresponds to the **smallest energy difference** during de-excitation.

$$\Delta E = E_3 - E_2$$

$$E_3 = -\frac{13.6}{9} = -1.51 \text{ eV}$$

$$E_2 = -\frac{13.6}{4} = -3.4 \text{ eV}$$

$$\Delta E = -1.51 - (-3.4) = 1.89 \text{ eV}$$

$$\lambda = \frac{hc}{\Delta E} = \frac{1240 \text{ eV nm}}{1.89 \text{ eV}}$$

$$\boxed{\lambda_{\max} \approx 656 \text{ nm}}$$

This is the first line of the Balmer series, lying in the visible region.

(c) 3 spectral lines.

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The wavelength of the emitted radiations in the two cases.

For $n_2 \xrightarrow{\lambda_L} n_1$

$$\Delta E = (-3.40 + 13.6)$$

$$= 10.20 \text{ eV}$$

$$\lambda_L = \frac{12.43 \times 10^{-7}}{10.2}$$

$$= 1.218 \times 10^{-7} \text{m}$$

$$\lambda_L = 1218 \text{Å}$$

For $n_3 \xrightarrow{\lambda_B} n_2$

$$\Delta E = (-1.5 + 3.4) = 1.9 \text{ eV}$$

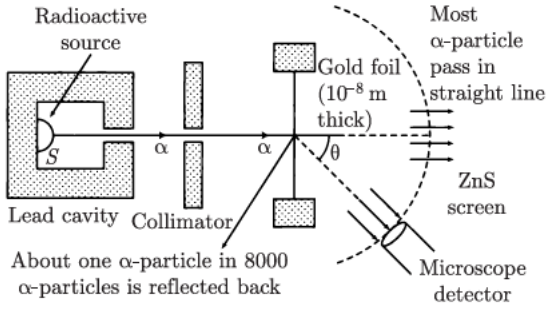
$$\lambda_B = \frac{12.43 \times 10^{-7}}{1.9}$$

$$= 6.54 \times 10^{-7} \text{m} = 6540 \text{Å}$$

$$\frac{\lambda_B}{\lambda_L} = \frac{6540 \text{Å}}{1281 \text{Å}} = 5.36$$

23

This experiment was suggested by Rutherford in 1911 as given in the figure below.



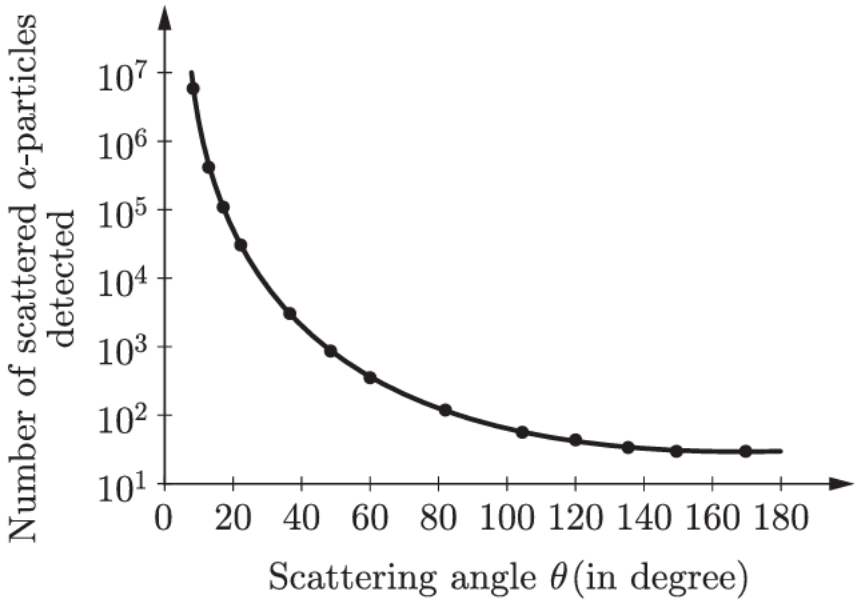
In this experiment, H Geiger and E Marsden took $^{214}_{83}$Bi as a source for α-particles. A collimated beam of α-particles of energy 5.5 MeV was allowed to fall on 2.1×10^{-7}m thick gold foil. The α-particles were observed through a rotatable detector consisting of a zinc sulphide screen and microscope and it was found that α-particles got scattered. These scattered α-particles produced scintillations on the zinc sulphide screen. Now, these scintillation were counted at different angles from the direction of incident beam.

Observations

Rutherford made the following observations from his experiment that are given below

1. Most of the α-particles passed through the gold foil without any appreciable deflection.
2. Only about 0.14% of the incident α-particles scattered by more than 1°.
3. About one α-particle in every 8000 α -particles deflected by more than 90°.

   The total number of α-particles (N) scattered through an angle (θ) is as shown in the below figure:



4. The force between α-particles and nucleus is given by,

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(2e)(Ze)}{r^2}$$

Where, r is the distance between the α-particles and the nucleus. This force is directed along the line joining the α-particle and the nucleus. The magnitude and direction of this force on α -particle continuously changes as it approaches the nucleus and recedes away from it.

24	a)Bohr's model assumes that a single electron revolves around a positively charged nucleus under the influence of the Coulomb force alone. This is valid for: H, He^{+}, and Li^{2+} because each has only one electron. For neutral helium, lithium, or heavier atoms, there are multiple electrons. Electron–electron repulsion and shielding of the nuclear charge make the force on any one electron more complicated. Therefore, Bohr's simple model cannot accurately explain their spectra.

(b) Hydrogen atom: ground state to $n = 4$

Energy in the nth state:

$$E_n = -\frac{13.6}{n^2}\ \text{eV}$$

$$E_1 = -13.6\ \text{eV}$$

$$E_4 = -\frac{13.6}{16} = -0.85\ \text{eV}$$

(i) Energy and wavelength of absorbed photon

$$\Delta E = E_4 - E_1$$

$$\Delta E = -0.85 - (-13.6)$$

$$\boxed{\Delta E = 12.75\ \text{eV}}$$

$$\lambda = \frac{hc}{\Delta E}$$

$$\lambda = \frac{1240\ \text{eV nm}}{12.75\ \text{eV}}$$

$$\boxed{\lambda = 97.2\ \text{nm}}$$

(ii) Maximum and minimum frequency of emitted photons

Maximum energy photon is emitted in the direct transition:

$$4 \rightarrow 1$$

$$E_{\max} = 12.75 \text{ eV}$$

$$f_{\max} = \frac{E_{\max}}{h} = \frac{12.75 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$\boxed{f_{\max} = 3.08 \times 10^{15} \text{ Hz}}$$

Minimum energy photon is emitted in:

$$4 \rightarrow 3$$

$$E_3 = -\frac{13.6}{9} = -1.51 \text{ eV}$$

$$\Delta E = E_4 - E_3$$

$$\Delta E = -0.85 - (-1.51) = 0.66 \text{ eV}$$

$$f_{\min} = \frac{0.66 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$\boxed{f_{\min} = 1.59 \times 10^{14} \text{ Hz}}$$

	(iii) Orbital angular momentum in $n = 4$ Bohr's quantization condition: $$L = \frac{nh}{2\pi}$$ For $n = 4$: $$\boxed{L = \frac{4h}{2\pi}}$$
25	i. a) The particle with b_1 suffers greater deflection ii. b) Decreases, because aluminium nuclei have lower positive charge iii. b) It experiences a repulsive force whose direction changes as it moves, producing a hyperbolic path iv. b) Very few would experience a force strong enough to deflect them through large angles **OR** a)Become double

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