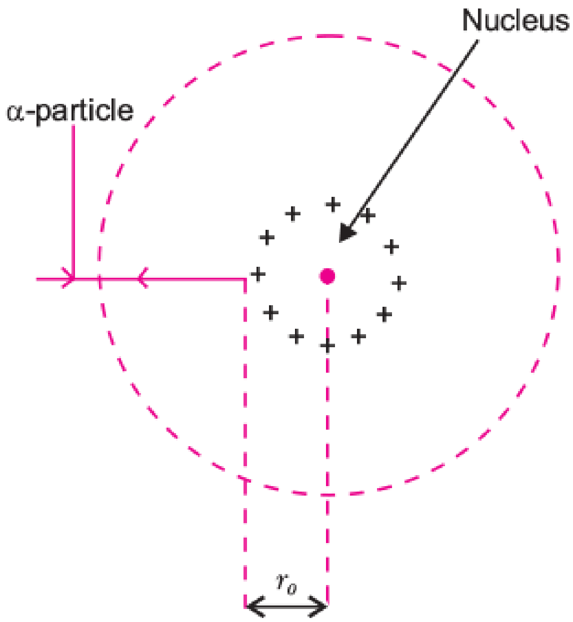
Short Answer Questions – I (PYQ)

Q. 1. Define the distance of closest approach. An a-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an a-particle of double the kinetic energy?
[CBSE Delhi 2017]

Ans. Distance of closest approach is the distance of charged particle from the centre of the nucleus, at which the entire initial kinetic energy of the charged particles gets converted into the electric potential energy of the system.

Distance of closest approach (r_0) is given by



$$mvr = \frac{nh}{2\pi}$$

If 'K' is doubled, r_o becomes $mvr = \frac{nh}{2\pi}$

Q. 2. Write two important limitations of Rutherford nuclear model of the atom.
[CBSE Delhi 2017]

Ans. Two important limitations of Rutherford Model are:

(i) According to Rutherford model, electron orbiting around the nucleus, continuously radiates energy due to the acceleration; hence the atom will not remain stable.

(ii) As electron spirals inwards; its angular velocity and frequency change continuously, therefore it should emit a continuous spectrum.

But an atom like hydrogen always emits a discrete line spectrum.

Q. 3. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times than that of the electron but having the same charge? [CBSE Central 2016]

Ans. The minimum energy required to free the electron from the ground state of the hydrogen atom is known as ionization energy.

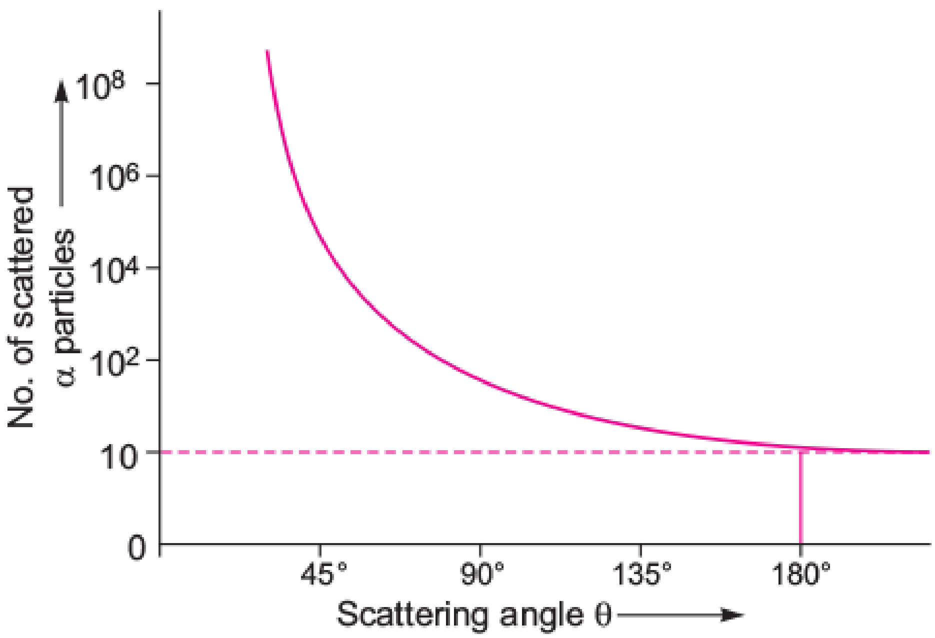
$$E_0 = \frac{me^4}{8\ \varepsilon^2 h^2},\ \ i.e.,\ E_0 \propto m$$

Therefore, ionization energy will become 200 times.

Q. 4. In an experiment on a-particle scattering by a thin foil of gold, draw a plot showing the number of particles scattered versus the scattering angle θ.

Why is it that a very small fraction of the particles are scattered at θ > 90°? [CBSE (F) 2013]

Ans. A small fraction of the alpha particles scattered at angle θ > 90° is due to the reason that if impact parameter 'b' reduces to zero, coulomb force increases, hence alpha particles are scattered at angle θ > 90°, and only one alpha particle is scattered at angle 180°.



Q. 5. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom. [CBSE Delhi 2017]

Ans.

Radius of ground state of hydrogen atom, $E_0 = \frac{me^4}{8\ \varepsilon^2 h^2}$,

According to de Broglie relation, $2\pi r = n\lambda$

For ground state, $n = 1$

$2 \times 3.14 \times 0.53 \times 10^{-10} = 1 \times \lambda$

$\therefore \lambda = 3.32 \times 10^{-10}\text{m} = 3.32\ \text{Å}$

Q. 6. When is Hα line in the emission spectrum of hydrogen atom obtained? Calculate the frequency of the photon emitted during this transition. [CBSE North 2016]

Ans. The line with the longest wavelength of the Balmer series is called Hα.

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

where λ = wavelength

$R = 1.097\times10^7\ \text{m}^{-1}$ (Rydberg constant)

When the electron jumps from the orbit with $n = 3$ to $n = 2$,

we have

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \quad \Rightarrow \quad \frac{1}{\lambda} = \frac{5}{36}R$$

The frequency of photon emitted is given by

$$\nu = \frac{c}{\lambda} = c \times \frac{5}{36}R$$

$$= 3 \times 10^8 \times \frac{5}{36} \times 1.097 \times 10^7\text{Hz} = 4.57 \times 10^{14}\,\text{Hz}$$

Q. 7. Calculate the de-Broglie wavelength of the electron orbiting in the n = 2 state of hydrogen atom. [CBSE Central 2016]

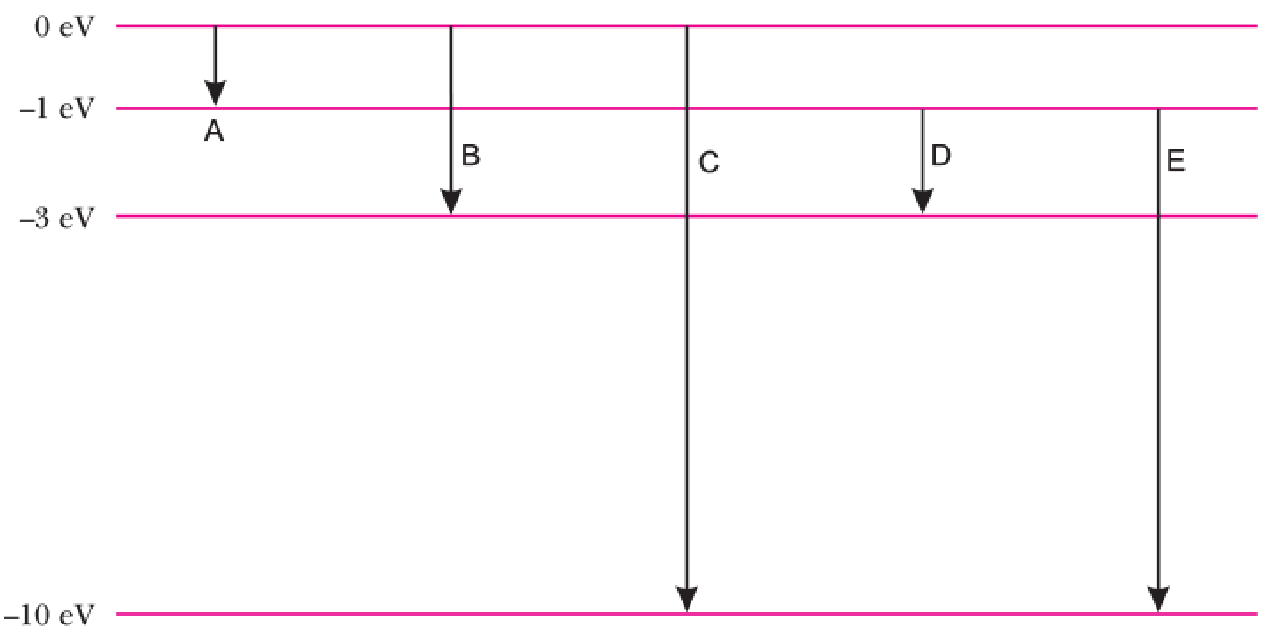
Ans. Kinetic Energy for the second state

$$E_k = \frac{13.6 \ \text{eV}}{n^2} = \frac{13.6 \ \text{eV}}{2^2} = \frac{13.6 \ \text{eV}}{4} = 3.4 \times 1.6 \times 10^{-19} \ J$$

$$\text{de Broglie wavelength } \lambda = \frac{h}{\sqrt{2 \, \text{mE}_k}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}}} = 0.067 \, \text{nm}$$

Q. 8. The energy levels of an atom are given below in the diagram.



Which of the transitions belong to Lyman and Balmer series? Calculate the ratio of the shortest wavelengths of the Lyman and the Balmer series of the spectra. [CBSE Chennai 2015]

Ans. Transition C and E belong to Lyman series.

Reason: In Lyman series, the electron jumps to lowest energy level from any higher energy levels.

Transition B and D belong to Balmer series.

Reason: The electron jumps from any higher energy level to the level just above the ground energy level.

The wavelength associated with the transition is given by

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

Ratio of the shortest wavelength

$$\lambda_L : \lambda_B = \frac{hc}{\Delta E_L} : \frac{hc}{\Delta E_B}$$

$$= \frac{1}{0-(-10)} : \frac{1}{0-(-3)} = 3 : 10$$

Q. 9. Show that the radius of the orbit in hydrogen atom varies as n2, where n is the principal quantum number of the atom. [CBSE Delhi 2015]

Ans. Hydrogen atom

Let *r* be the radius of the orbit of a hydrogen atom. Forces acting on electron are centrifugal force (F_c) and electrostatic attraction (F_e)

At equilibrium, $F_c = F_e$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

According to Bohr's postulate

$$mvr = \frac{nh}{2\pi} \quad \Rightarrow \quad v = \frac{nh}{2\pi mr}$$

$$m\left(\frac{nh}{2\pi mr}\right)^2 \cdot \frac{1}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \quad \Rightarrow \quad \frac{mn^2h^2}{4\pi^2m^2r^2.r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$r = \frac{m^2h^2\varepsilon_0}{\pi me^2} \quad \Rightarrow \therefore \quad r \propto n^2$$

Q. 10. When the electron orbiting in hydrogen atom in its ground state moves to the third excited state, show how the de Broglie wavelength associated with it would be affected. [CBSE Ajmer 2015]

Ans.

We know,

de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\mathrm{mv}}$

$\Rightarrow \quad \lambda \propto \frac{1}{v},$

Also $\quad v \propto \frac{1}{n}$

$\therefore \quad \lambda \propto n$

$\therefore$ de Broglie wavelength will increase.

Q. 11. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron change? Justify your answer. [CBSE Allahabad 2015]

Ans. de Broglie wavelength associated with a moving charge particle having a KE 'K' can be given as

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2\,\mathrm{mK}}} \qquad \ldots(i) \qquad \left[K = \frac{1}{2}\mathrm{mv}^2 = \frac{p^2}{2m}\right]$$

The kinetic energy of the electron in any orbit of hydrogen atom can be given as

$$K = -E = -\left(\frac{13.6}{n^2}\mathrm{eV}\right) = \frac{13.6}{n^2}\mathrm{eV} \qquad \ldots(ii)$$

Let K_1 and K_4 be the KE of the electron in ground state and third excited state, where $n_1 = 1$ shows ground state and $n_2 = 4$ shows third excited state.

Using the concept of equation (*i*) & (*ii*), we have

$$\frac{\lambda_1}{\lambda_4} = \sqrt{\frac{K_4}{K_1}} = \sqrt{\frac{n_1^2}{n_2^2}}$$

$$\frac{\lambda_1}{\lambda_4} = \sqrt{\frac{1^2}{4^2}} = \frac{1}{4}$$

$$\Rightarrow \qquad \lambda_1 = \frac{\lambda_4}{4}$$

i.e., the wavelength in the ground state will decrease.

Q. 12. The kinetic energy of the electron orbiting in the first excited state of hydrogen atom is 3.4 eV. Determine the de Broglie wavelength associated with it. [CBSE (F) 2015]

Ans. Kinetic energy of the electron in the first excited state is 3.4 eV, i.e.,

$$\frac{p^2}{2m} = 3.4 \text{ eV} = 3.4 \times 1.6 \times 10^{-19} \text{ J}$$

$$p^2 = 2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}$$

$$p = \sqrt{18.2 \times 3.4 \times 1.6 \times 10^{-50}}$$

$$= \sqrt{99.008} \times 10^{-25} = 9.95 \times 10^{-25}$$

de Broglie wavelength, $\lambda = \frac{h}{p}$

$$= \frac{6.63 \times 10^{-34}}{9.95 \times 10^{-25}} = 0.67 \times 10^{-9} = 0.67 \text{ nm}$$

Short Answer Questions – I (OIQ)

Q. 1. In Bohr's theory of hydrogen atom, calculate the energy of the photon emitted during a transition of the electron from the first excited state to the ground state. Write in which region of the electromagnetic spectrum this transition lies.

Ans. The energy levels of hydrogen atom are given by

$$E_n\left(=-\frac{Rhc}{n^2}\right)=\frac{13.6}{n^2}\text{eV}$$

For ground state, $n=1$

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

For first excited state, $n = 2$

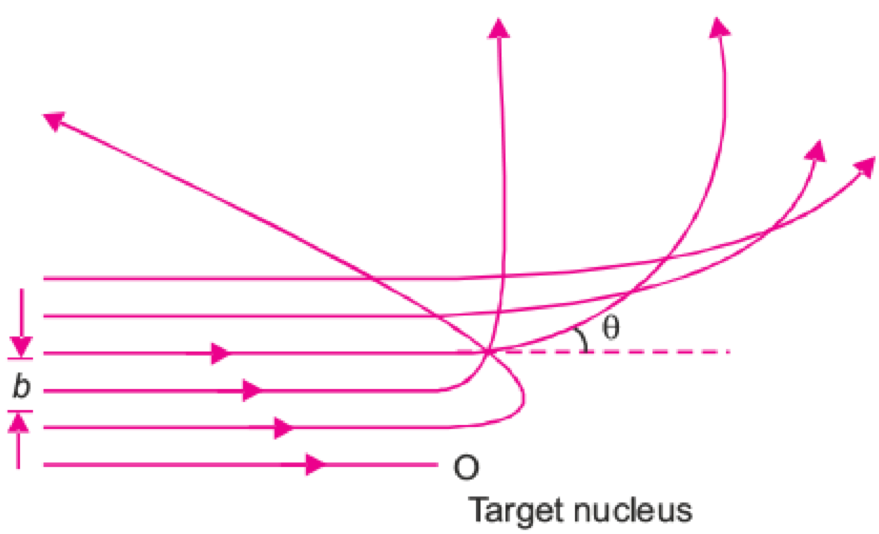
$$E_2 = -\frac{13.6}{4} = -3.4 \text{ eV}$$

∴ Energy of photon emitted

$$h\nu = E_2 - E_1 = -3.4 - (-13.6) \text{ eV} = 10.2 \text{ eV}$$

As transition from higher state to n=1 corresponds to Lyman series so the corresponding transition belongs to Lyman series.

Q. 2. The trajectories, traced by different α-particles, in Geiger-Marsden experiment were observed as shown in the figure.



(i) What names are given to the symbols 'b' and 'θ' shown here?

(ii) What can we say about the values of b for (i) θ = 0° (ii) θ = p radians? [HOTS]

Ans. (i) The symbol 'b' represents impact parameter and 'θ' represents the scattering angle.

(ii) (i) When θ = 0°, the **impact parameter** will be maximum and represent the **atomic size.**

(ii) When θ = π radians, the impact parameter 'b' will be minimum and represent the nuclear size.

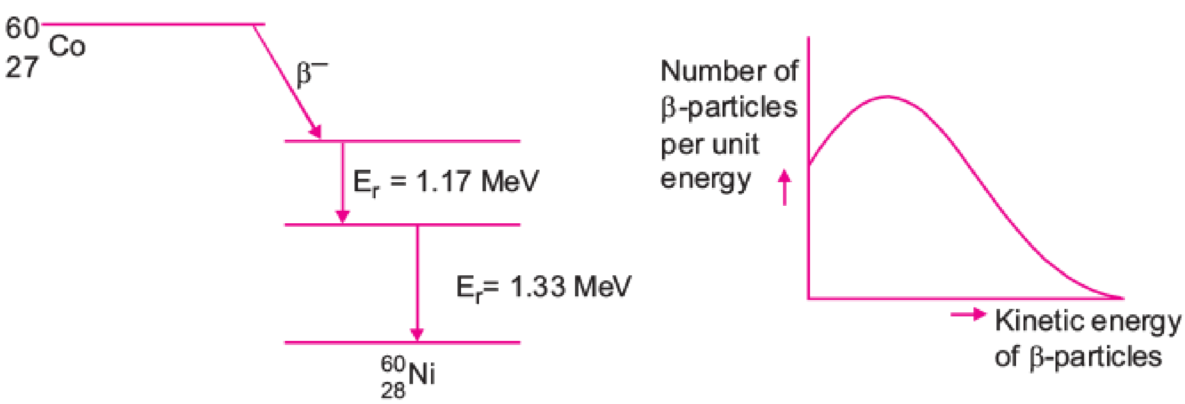
Q. 3. Which is easier to remove: orbital electron from an atom or a nucleon from a nucleus? [HOTS]

Ans. It is easier to remove an orbital electron from an atom. The reason is the binding energy of orbital electron is a few electron-volts while that of nucleon in a nucleus is quite large (nearly 8 MeV). This means that the removal of an orbital electron requires few electron volt energy while the removal of a nucleon from a nucleus requires nearly 8 MeV energy.

Q. 4. Answer the following questions.

(i) Draw the energy level diagram showing the emission of b-particles followed by γ-rays by a $^{60}_{27}\text{Co}$ nucleus.

(ii) Plot of distribution of KE of b-particles is shown in fig. (b).



(a) Energy level diagram *(b)* Energy distribution of β-particles

The energy spectrum of b-particles is continuous because an **antineutrino** is simultaneously emitted in β-decay; the total energy released in b-decay is shared by b-particle and the antineutrino so that momentum of system may remain conserved.

Q. 5. What is the longest wavelength of photon that can ionize a hydrogen atom in its ground state? Specify the type of radiation.

Ans.

Since, the energy of the incident photon $= h\nu = \frac{hc}{\lambda} = 13.6 \text{ eV}$

$$\lambda = \frac{6.6\times10^{-34}\times3\times10^{8}}{13.6\times1.6\times10^{-19}}$$

$$\lambda = 0.910 \times 10^{-10} \text{ m}$$

This radiation is in ultraviolet region.