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

Where,

R_y = Rydberg constant = $1.097 \times 10^7\ m^{-1}$

λ= Wavelength of radiation emitted by the transition of the electron

For n = 3, we can obtain λas:

$$\frac{1}{\lambda}=1.097\times10^7\left(\frac{1}{1^2}-\frac{1}{3^2}\right)$$

$$=1.097\times10^7\left(1-\frac{1}{9}\right)=1.097\times10^7\times\frac{8}{9}$$

$$\lambda=\frac{9}{8\times1.097\times10^7}=102.55\ nm$$

If the electron jumps from n = 2 to n = 1, then the wavelength of the radiation is given as:

$$\frac{1}{\lambda}=1.097\times10^7\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

$$=1.097\times10^7\left(1-\frac{1}{4}\right)=1.097\times10^7\times\frac{3}{4}$$

$$\lambda=\frac{4}{1.097\times10^7\times3}=121.54\ nm$$

If the transition takes place from n = 3 to n = 2, then the wavelength of the radiation is given as:

$$\frac{1}{\lambda}=1.097\times10^7\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$=1.097\times10^7\left(\frac{1}{4}-\frac{1}{9}\right)=1.097\times10^7\times\frac{5}{36}$$

$$\lambda=\frac{36}{5\times1.097\times10^7}=656.33\ nm$$

This radiation corresponds to the Balmer series of the hydrogen spectrum.

Hence, in Lyman series, two wavelengths i.e., 102.5 nm and 121.5 nm are emitted. And in the Balmer series, one wavelength i.e., 656.33 nm is emitted.

Question 12.10:

In accordance with the Bohr's model, find the quantum number that characterises the earth's revolution around the sun in an orbit of radius 1.5×10^{11} m with orbital speed 3 $\times$ 10^4 m/s. (Mass of earth = 6.0×10^{24} kg.)

Answer

Radius of the orbit of the Earth around the Sun, $r = 1.5 \times 10^{11}$ m

Orbital speed of the Earth, $v = 3 \times 10^4$ m/s

Mass of the Earth, $m = 6.0 \times 10^{24}$ kg

According to Bohr's model, angular momentum is quantized and given as:

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

Where,

h = Planck's constant = 6.62×10^{-34} Js

n = Quantum number

$$\therefore n = \frac{mvr2\pi}{h}$$

$$= \frac{2\pi \times 6 \times 10^{24} \times 3 \times 10^4 \times 1.5 \times 10^{11}}{6.62 \times 10^{-34}}$$

$$= 25.61 \times 10^{73} = 2.6 \times 10^{74}$$

Hence, the quanta number that characterizes the Earth' revolution is 2.6×10^{74}.

Question 12.11:

Answer the following questions, which help you understand the difference between Thomson's model and Rutherford's model better.

(a) Is the average angle of deflection of α-particles by a thin gold foil predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?

(b) Is the probability of backward scattering (i.e., scattering of α-particles at angles greater than 90°) predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?

(c) Keeping other factors fixed, it is found experimentally that for small thickness t, the number of α-particles scattered at moderate angles is proportional to t. What clue does this linear dependence on t provide?

(d) In which model is it completely wrong to ignore multiple scattering for the calculation of average angle of scattering of α-particles by a thin foil?

Answer

(a) about the same

The average angle of deflection of α-particles by a thin gold foil predicted by Thomson's model is about the same size as predicted by Rutherford's model. This is because the average angle was taken in both models.

(b) much less

The probability of scattering of α-particles at angles greater than 90° predicted by Thomson's model is much less than that predicted by Rutherford's model.

(c) Scattering is mainly due to single collisions. The chances of a single collision increases linearly with the number of target atoms. Since the number of target atoms increase with an increase in thickness, the collision probability depends linearly on the thickness of the target.

(d) Thomson's model

It is wrong to ignore multiple scattering in Thomson's model for the calculation of average angle of scattering of α–particles by a thin foil. This is because a single collision causes very little deflection in this model. Hence, the observed average scattering angle can be explained only by considering multiple scattering.

Question 12.12:

The gravitational attraction between electron and proton in a hydrogen atom is weaker than the coulomb attraction by a factor of about 10^{-40}. An alternative way of looking at this fact is to estimate the radius of the first Bohr orbit of a hydrogen atom if the electron and proton were bound by gravitational attraction. You will find the answer interesting.

Answer

Radius of the first Bohr orbit is given by the relation,

$$r_1 = \frac{4\pi \epsilon_0 \left(\frac{h}{2\pi}\right)^2}{m_e e^2} \qquad \dots (1)$$

Where,

$\in_0$ = Permittivity of free space

h = Planck's constant = 6.63×10^{-34} Js

m_e = Mass of an electron = 9.1×10^{-31} kg

e = Charge of an electron = 1.9×10^{-19} C

m_p = Mass of a proton = 1.67×10^{-27} kg

r = Distance between the electron and the proton

Coulomb attraction between an electron and a proton is given as:

$$F_C = \frac{e^2}{4\pi \in_0 r^2} \quad \text{... (2)}$$

Gravitational force of attraction between an electron and a proton is given as:

$$F_G = \frac{Gm_p m_e}{r^2} \quad \text{... (3)}$$

Where,

G = Gravitational constant = 6.67×10^{-11} N m^2/kg^2

If the electrostatic (Coulomb) force and the gravitational force between an electron and a proton are equal, then we can write:

$\therefore F_G = F_C$

$$\frac{Gm_p m_e}{r^2} = \frac{e^2}{4\pi \in_0 r^2}$$

$$\therefore \frac{e^2}{4\pi \in_0} = Gm_p m_e \quad \text{... (4)}$$

Putting the value of equation (4) in equation (1), we get:

*********** END **********