PHYSICS

Class XII

Chapter 12 -Atoms

1 Mark Questions

Question 1.
Define ionisation energy. What is its value for a hydrogen atom?
Answer:
Ionisation energy : The energy required to knock out an electron from an atom is called ionisation energy of the atom.
For hydrogen atom it is 13.6 eV.

Question 2.
Write the expression for Bohr's radius in hydrogen atom.
Answer:
Bohr's radius in hydrogen atom,

$$r_1 = \frac{\varepsilon_0 h^2}{\pi m e^2} = \mathbf{0.5.29 \times 10^{-10}\ m}$$

Question 3.
What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?
Answer:

Radius of Bohr's stationary orbits, $r = \dfrac{n^2 h}{4\pi^2 m K e^2}$

Clearly, $r \propto n^2$ and in ground state, $n = 1$

For 1st excited state, $n = 2$

$\therefore$ Ratio of radii of the orbits $= \dfrac{2^2}{1^2} = \dfrac{4}{1} = \mathbf{4 : 1}$

Question 4.
The radius of innermost electron orbit of a hydrogen atom is 5.3 × 10^{-11} m. What is the radius of orbit in the second excited state?
Answer:

$r = n^2 \times 5.3 \times 10^{-11}$ m

$\therefore$ Radius of second excited state ($n = 3$) is :

$r = (3)^2 \times 5.3 \times 10^{-11}\ \text{m} = 9 \times 5.3 \times 10^{-11}\ \text{m}$

$= \mathbf{4.77 \times 10^{-10}\ m}$

Question 5.
Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from

its
(i) second permitted energy level to the first level, and
(ii) the highest permitted energy level to the first permitted level.
Answer:
We have,

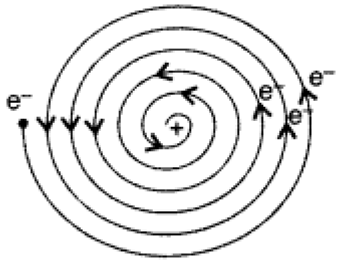
$$E_{2-1} = \text{const.}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \text{const.}\ \frac{3}{4}$$

and $$E_{\infty \to 2} = \text{const.}\left(\frac{2}{2^2} - \frac{1}{\infty^2}\right) = \text{const.}\ \frac{1}{4}$$

$\therefore$ Ratio = 3 : 1

Question 6.
The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of electron in this state?
Answer:
Kinetic energy, K_e = + T.E. = 13.6 eV
Potential energy, P_e = 2 T.E. = 2 (-13.6) = – 27.2 eV

Question 7.
Why is the classical (Rutherford) model for an atom—of electron orbitting around the nucleus—not able to explain the atomic structure?
Answer:
As the revolving electron loses energy continuously, it must spiral inwards and eventually fall into the nucleus. So it was not able to explain the atomic structure.

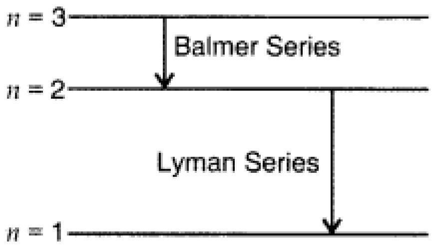


Question 8.
When is Ha line of the Balmer series in the emission spectrum of hydrogen atom obtained?
Answer:
Balmer series is obtained when an electron jumps to the second orbit (n_1 = 2) from any orbit n_2 = n > 2 .

Question 9.
What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state?
Answer:
For third excited state, n_2 = 4, and n_1 = 3, 2, 1 Hence there are 3 spectral lines.

2 Mark Questions

Question 1.
(i) In hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.
(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.
Answer:
(i) $n_f = 2, \quad n_i = 3$ *Balmer series*
$n_i = 2, \quad n_f = 1$ *Lyman series*



(ii) $$\frac{1}{\lambda_B} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36}R$$

...where $\left[\begin{array}{l}\lambda_B \text{ is the wavelength for Balmer series.} \\ \lambda_L \text{ is the wavelength for Lyman series.}\end{array}\right.$

and $$\frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R\left[\frac{1}{1} - \frac{1}{4}\right] = \frac{3}{4}R$$

$$\therefore \frac{\lambda_B}{\lambda_L} = \frac{36}{5} \times \frac{3}{4} = \frac{27}{5}$$

$\therefore$ ***Ratio*** $= \lambda_B : \lambda_L =$ **27 : 5**

Question 2.
(i) In hydrogen atom, an electron undergoes transition from third excited state to the second excited state and then to the first excited state. Identify the spectral series to which these transitions belong.
(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.
Answer:
(i) These transitions belong to :
1. *Paschen series*, 2. *Balmer series*

(ii) $$\frac{1}{\lambda_P} = R\left[\frac{1}{9} - \frac{1}{16}\right] = R\left[\frac{16-9}{144}\right] = \frac{7}{144}R$$

$$\frac{1}{\lambda_B} = R\left[\frac{1}{4} - \frac{1}{9}\right] = R\left[\frac{9-4}{36}\right] = \frac{5}{36}R$$

$$\therefore \frac{\lambda_P}{\lambda_B} = \frac{144}{7} \times \frac{5}{36} = \frac{20}{7}$$

$\therefore$ ***Ratio*** **= 20 : 7**

Question 3.
In hydrogen atom, an electron undergoes transition from 3rd excited state to the first excited state

and then to the ground state. Identify the spectral series to which these transitions belong.
(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

Answer:
(i) These transitions belong to :
1. Balmer series,
2. Lyman series

$$(ii)\quad \frac{1}{\lambda_B} = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3}{16}R,$$

$$\frac{1}{\lambda_L} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R$$

$$\therefore \quad \frac{\lambda_B}{\lambda_L} = \frac{16}{3} \times \frac{3}{4} = \mathbf{4}$$

...where $\left[\begin{array}{l}\lambda_B \text{ is the wavelength for Balmer series.}\\ \lambda_L \text{ is the wavelength for Lyman series.}\end{array}\right.$

$$\therefore \quad Ratio = \lambda_B : \lambda_L = \mathbf{4 : 1}$$

Question 4.
Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?
Answer:
Expression for total energy of electron in H-atom using Rutherford model : As per Rutherford model of atom, centripetal force (F_c) required to keep electron revolving in orbit is provided by the electrostatic force (Fe) of attraction between the revolving electron and nucleus.

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{ee}{4\pi\varepsilon_0 r^2} \qquad \ldots(i)$$

$$r = \frac{e^2}{4\pi\varepsilon_0 mv^2} \qquad \ldots(ii)$$

$$\text{From equation } (i),\ \text{KE} = \frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r} \qquad \ldots(iii)$$

$$\text{PE} = \frac{e(-e)}{4\pi\varepsilon_0 r} = \frac{-e^2}{4\pi\varepsilon_0 r}$$

$$\therefore \quad \text{TE} = \text{KE} + \text{PE} = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r} = \frac{-e^2}{8\pi\varepsilon_0 r}$$

The negative sign indicates that the revolving electron is bound to the positive nucleus.

Question 5.
Using Bohr's postulates of the atomic model, derive the expression for radius of nth electron orbit.

Hence obtain the expression for Bohr's radius.
Answer:
Basic postulates of Bohr's atomic model:
(i) Every atom consists of a central core called nucleus in which entire positive charge and mass of the atom are concentrated. A suitable number of electrons revolve around the nucleus in circular orbit. The centripetal force required for revolution is provided by the electrostatic force of attraction between the electron and the nucleus.
(ii) Electron can resolve only in certain discrete non-radiating orbits, called stationary orbit. Total angular momentum of the revolving electron in an integral multiple of h/2π.
… where [h is plank constant]

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

(iii) The radiation of energy occurs only when an electron jumps from one permitted orbit to another. The difference in the total energy of electron in the two permitted orbit is absorbed when the electron jumps from inner to the outer orbit and emitted when electron jumps from outer to inner orbit.

Radii of Bohr's stationary orbits. According to Bohr's postulates, angular momentum of electron for any permitted orbit is,

$$mvr = \frac{nh}{2\pi} \quad \text{or} \quad v = \frac{nh}{2\pi mr} \qquad \ldots(i)$$

Also, according to Bohr's postulates, the centripetal force is equal to electrostatic force between the electron and nucleus.

$$\frac{mv^2}{r} = \mathrm{K}\frac{Ze \cdot e}{r^2} \quad \text{or} \quad \frac{m}{r} \cdot \frac{n^2h^2}{4\pi^2m^2r^2} = \frac{\mathrm{K}Ze^2}{r^2}$$

$$\text{or} \quad r \cdot 4\pi^2 m\mathrm{K}Ze^2 = n^2h^2 \quad \therefore \boxed{r = \frac{n^2h^2}{4\pi^2 m\mathrm{K}Ze^2}} \qquad \ldots(ii)$$

$$r = \frac{h^2}{4\pi mke^2}$$

It is the expression for Bohr's radius, which is about 0.5 Å
For first orbit of hydrogen atom, $n = 1$, Z = 1 then we have $\boldsymbol{r} = \mathbf{0.529Å}$

Question 6.
Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.
Answer:
When an electron moves around hydrogen nucleus, the electrostatic force between electron and hydrogen nucleus provides necessary centrepetal force.

$$\frac{mv^2}{r} = \frac{1}{4\pi \epsilon_0}\frac{e^2}{r^2} \quad \text{or} \quad mv^2r = \frac{e^2}{4\pi \epsilon_0} \qquad \ldots(i)$$

Also we know from Bohr's postulate,

$$mvr = \frac{nh}{2\pi} \qquad \text{or } m^2v^2r^2 = \frac{n^2h^2}{4\pi^2} \qquad \ldots(ii)$$

Dividing (ii) by (i), we have

$$mr = \frac{n^2h^2}{4\pi^2} \times \frac{4\pi\,\epsilon_0}{e^2}$$

$$\therefore \quad r = \frac{n^2h^2}{4\pi^2me^2}.4\pi\epsilon_0 \quad \therefore\ r \propto n^2$$

Question 7.

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.

Answer:

Given : For 3rd excited state $n_2 = 4$

For ground state, $n_1 = 1 \quad R = 1.097 \times 10^7\ m^{-1}$

We know $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$\Rightarrow \quad \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = R \times \frac{15}{16}$$

$$\text{or} \quad \lambda = \frac{1}{R} \times \frac{16}{15} = \frac{1}{1.097 \times 10^7} \times \frac{16}{15}$$

$$= 0.97 \times 10^{-7}\ m$$

$$= 97 \times 10^{-9}\ m = 97\ nm = 970\ \text{Å}$$

It lies in the ultra-violet region.

Question 8.

Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infra-red, visible, ultraviolet) of hydrogen spectrum does this wavelength lie?

Answer:

In Balmer series, an electron jumps from higher orbits to the second stationary orbit ($n_f = 2$). Thus for this

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \text{ and in this case}$$

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

R (Rydberg's constant) = $1.097 \times 10^7\ m^{-1}$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \text{ and in this case}$$

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

R (Rydberg's constant) $= 1.097 \times 10^7 \text{ m}^{-1}$

For the shortest wavelength, $n_i = \infty$;

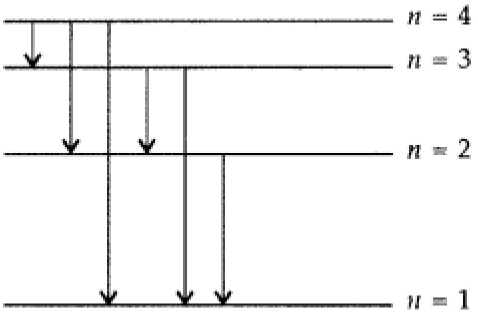
Hence, $\frac{1}{\lambda} = \frac{R}{4}$

or $\lambda = \frac{4}{R} = \frac{4}{1.097 \times 10^7}$ m

$= 3.646 \times 10^{-7}$ m $=$ **3646 Å**

It will lie in ultra-violet region.

Question 9.
The figure shows energy level diagram of hydogen atom



(a) Find out the transition which results in the emission of a photon of wavelength 496 nm.
(b) Which transition corresponds to the emission of radiation of maximum wavelength? Justify your answer.
Answer:
(a) Transition emitting wavelength λ = 496 nm The given wavelength lies in visible region (Balmer series) when,

$n_1 = 2, n_2 = 4$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad [R = 1.097 \times 10^7 \text{ m}^{-1}]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 1.097 \times 10^7 \times \frac{3}{16}$$

$$\Rightarrow \quad \lambda = \frac{16}{3} \times \frac{10^{-7}}{1.097} = 486 \text{ nm} \approx 496 \text{ nm}$$

Hence the transition from, $n_2 = 4$ to $n_1 = 2$

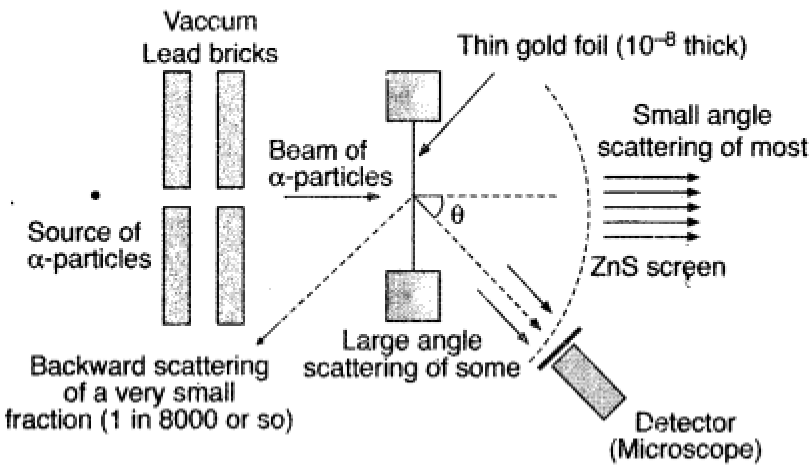
(b) Transition corresponding to emission of maximum wavelength,

$$E = hv = \frac{hc}{\lambda} \text{ or } E \propto \frac{1}{\lambda}$$

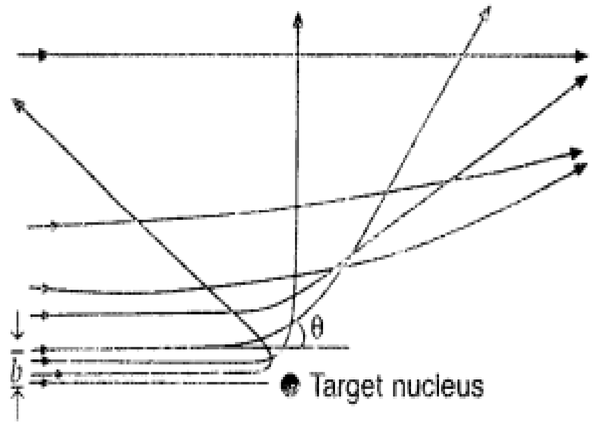
which means that the maximum wavelength emmission will be there when the energy level difference is

minimum. From the given energy level diagram, it corresponds to :
$n_2 = 4$ to $n_1 = 3$.

Question 10.
In Rutherford scattering experiment, draw the trajectory traced by a-particles in the coulomb field of target nucleus and explain how this led to estimate the size of the nucleus.
Answer:
Note: The Rutherford scattering experiment is also known as the Geiger Marsden experiment.
(*a*) (*i*) **Geiger-Marsden experiment**



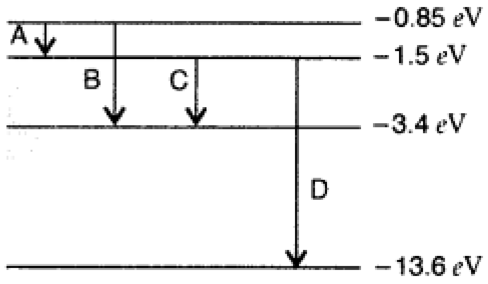
(ii) For most of the α-particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go right through the foil.
(iii) Trajectory of α-particles



It gives an estimate of the size of nucleus, that it relatively very very small as compared to the size of atom.

4 Mark Questions

Question 1.
The energy level diagram of an element is given. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm.



Answer:

Here $\lambda = 102.7\ \text{nm} = 102.7 \times 10^{-9}$ m

The energy of the emitted photon is,

$$E = \frac{hC}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{102.7 \times 10^{-9}}$$

$$= \frac{19.878 \times 10^{-26}}{102.7 \times 10^{-9}} = 1.9355 \times 10^{-18}\ \text{J}$$

$\therefore$ Energy corresponds $= \frac{1.9355 \times 10^{-18}}{1.6 \times 10^{-19}}$ eV

$= 12.097\ \text{eV} \approx \mathbf{12.1\ eV}$

This energy corresponds to the transition D for which the energy change

$= -1.5 - (-13.6) = 12.1$ eV

Question 2.
The ground state energy of hydrogen atom is -13.6 eV.
(i) What is the kinetic energy of an electron in the 2^{nd} excited state?
(ii) If the electron jumps to the ground state from the 2^{nd} excited state, calculate the wavelength of the spectral line emitted.
Answer:

(*ii*) $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \Rightarrow \frac{1}{\lambda} = R\left[1 - \frac{1}{9}\right]$

$\Rightarrow \frac{1}{\lambda} = R\left[\frac{8}{9}\right] \qquad \Rightarrow \frac{1}{\lambda} = \frac{8}{9} R$

$\Rightarrow \lambda = \frac{9}{8R} = \frac{9}{8 \times 1.1 \times 10^{7}}\ \text{m}^{-1}$

($\because$ **Rydberg constant, $R = 1.1 \times 10^{7}\ \text{m}^{-1}$**)

$\therefore$ $\boldsymbol{\lambda = 1.02 \times 10^{-7}\ \text{m}}$

(i) K.E. of electron in the 2[nd] excited state,

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

$$\Rightarrow E_n = -\frac{13.6}{3^2} = -1.51 \text{ eV}$$

[$\because$ for 2[nd] excited state $n = 3$]

7 Marks Questions

Question 1.
The ground state energy of hydrogen atom is -13.6 eV.
(i) What is the potential energy of an electron in the 3[rd] excited state?
(ii) If the electron jumps to the ground state from the 3[rd] excited state, calculate the wavelength of the photon emitted.
Answer:

Energy of an electron in n[th] orbit $= \frac{-13.6}{n^2}$eV

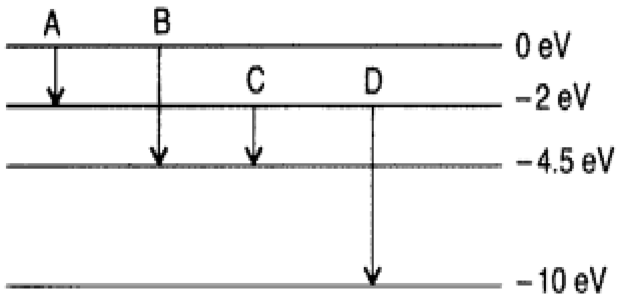
(i) For 3[rd] excited state, $n = 4$

$$\therefore E_4 = \frac{-13.6}{(4)^2} = -0.85 \text{ eV}$$

(ii) $$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = R\left(1 - \frac{1}{16}\right) = \frac{15}{16}R$$

$$\lambda = \frac{16}{15R} = \frac{160}{15 \times 1.1 \times 10^7} = \frac{160}{165} \times 10^{-7}$$
$$= \mathbf{0.97\ 10^{-7}\ m^{-1}}$$

(a) The energy levels of an atom are as shown here. Which of them will result in the transition of a photon of wavelength 275 nm?



(a) 275 nm corresponds to ultraviolet radiation.

Using $E = \frac{hC}{\lambda}$ and $h = 4.14 \times 10^{-15}$ eV

$$\lambda = \frac{hC}{E} = \frac{4.14 \times 10^{-15} eV \times 3 \times 10^{8}}{E}$$

$$= \frac{12.42 \times 10^{-7}}{E}$$

$$\lambda_A = \frac{hC}{E} = \frac{12.42 \times 10^{-7}}{2}$$

$$= 6.21 \times 10^{-7} \text{ m} = \mathbf{621 \text{ nm}}$$

$$\lambda_B = \frac{12.42 \times 10^{-7}}{4.5} = \frac{24.84 \times 10^{-7}}{9}$$

$$= 2.76 \times 10^{-7} = \mathbf{276 \text{ nm}}$$

$\therefore$ λ_B corresponds to 276 nm.

$$\lambda_C = \frac{12.42 \times 10^{-7}}{2.5} = \frac{24.84 \times 10^{-7}}{5}$$

$$= 4.968 \times 10^{-7} \text{ m} = \mathbf{496.8 \text{ nm}}$$

$$\lambda_D = \frac{12.42 \times 10^{-7}}{8} = 1.552 \times 10^{-7}$$

$$= \mathbf{155.2 \text{ nm}}$$

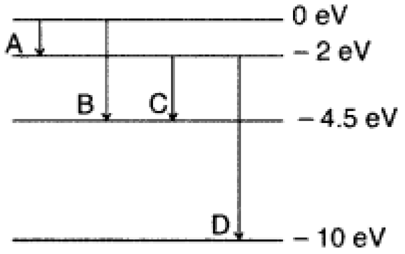
(b) The maximum wavelength of the emission corresponds to the radiation due to the transition A.

Question 2.

The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions correspond to emission of radiation of

(i) maximum and

(ii) minimum wavelength ?



Answer:

Energy of photon wavelength 275 nm

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{275\times10^{-9}\times1.6\times10^{-19}}.eV = 4.5\ eV$$

This componds to transition 'B'.

(*i*) *Element A* has radiation of maximum wavelength *621 nm*.

(*ii*) *Element D* has radiation of minimum wavelength *155 nm*.

Question 3.

(a) Using Bohr's second postulate of quantization of orbital angular momentum show that the circumference of the electron in the n,h orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it.

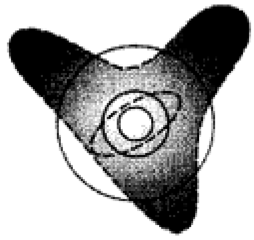
(b) The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state?

Answer:

(a) According to the de-Broglie hypothesis, this electron is also associated with wave character.

Hence a circular orbit can be taken to be a stationary energy state only if it contains an integral number of de- Broglie wavelengths i.e. we must have

$2\pi r = n\lambda$



But $\lambda = \frac{h}{mv}$

According to Bohr's-second postulate

$mvr = n\frac{h}{2\pi}$ where $[n = 1, 2, 3]$

$2\pi r = n\frac{h}{mv}$ where $[\ \lambda = \frac{h}{mv}]$

$2\pi r = n\lambda$

Hence the circumference of the electron in the n^{th} orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it.

(b) For third excited state n = 4

For ground state n = 1

Hence, possible transitions are :

$n_i = 4$ to $n_f = 3, 2, 1$
$n_i = 3$ to $n_f = 2, 1$
$n_i = 2$ to $n_f = 1$

$\therefore$ Total number of transitions = 6

In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of Z = 80, when an α-particle of 8 MeV energy impinges on it before it comes momentarily to rest and reverses its direction. How will the distance of closest approach be affected when the kinetic energy of the α-particle is doubled?
Answer:

$$r_0 = \frac{2K\tau e^2}{K_\alpha} \qquad \text{where } [K_\alpha = 8 \times 1.6 \times 10^{-13}\ \text{J}]$$

Atomic number, Z = 80

$$\text{where } [K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{NM}^2\text{C}^{-2}$$

$$\therefore \quad r_0 = \frac{2 \times 9 \times 10^9 \times \cancel{80}^{10} \times [1.6 \times 10^{-19}]^2}{\cancel{8} \times 1.6 \times 10^{-13}}$$

$$= \frac{18 \times 10^{10} \times \cancel{1.6} \times 106 \times 10^{-38}}{\cancel{1.6} \times 10^{-13}}$$

$$= 18 \times 1.6 \times 10^{10+13} \times 10^{-38}$$

$$= 18 \times 1.6 \times 10^{-38+23} = 18 \times 1.6 \times 10^{-15}$$

$$= 2.88 \times 10^{-14}\ \text{m} = \mathbf{28.8\ fm}$$

When kinetic energy of a-particle is doubled, then distance of closest approach becomes half

$$\text{As} \quad r_0 \propto \frac{1}{K_\alpha} \qquad \Rightarrow K'_\alpha = 2K_\alpha$$

$$r'_0 \propto \frac{1}{2K_\alpha} \qquad \Rightarrow r'_0 \propto \frac{1}{2} r_0$$

The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -0.85 eV to -3.4 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?
Answer:

Energy of emitted photon, $hv = E_2 - E_1$

$$= -0.85 - (-3.4) = 2.55\ \text{eV}$$

$$= 2.55 \times 1.6 \times 10^{-19}\ \text{J}$$

$$\therefore \quad \lambda v = \frac{hC}{E_2 - E_1} = \frac{hC}{2.55 \times 1.6 \times 10^{-19}}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.55 \times 1.6 \times 10^{-19}} = \frac{19.8 \times 10^{-26}}{4.08 \times 10^{-19}}$$

$$= 4.853 \times 10^{-7}\ \text{m} = \mathbf{4853\ Å}$$

(ii) This wavelength belongs to Balmer series of hydrogen spectrum.

Fill in the blanks

1. What did Rutherford's alpha particle experiment prove--------------(Nucleus)

2. Why was Rutherford's atomic model unstable----------------------

(Electrons do not remain in orbit)

3. Balmer series lies in which spectrum is ------------------------(Visible)

4. According to the classical theory, the circular path of the electrons is---------(Spiral)

Multiple choice questions

1. Electrons in the atom are held to the nucleus by

a. Nuclear Force
b. Coulomb's Force
c. Gravitational Force
d. Van Der Waal's Force

Answer: (b) Columb's Force

Explanation: Electrons in the atom are held to the nucleus by Coulomb's Force.

2**.** The electrons of Rutherford's model would be expected to lose energy because

a. They jump on the nucleus
b. They move randomly
c. Radiate electromagnetic waves
d. Escape from the atom

Answer: (c) Radiate electromagnetic waves.

Explanation: The electrons of Rutherford's model would be expected to lose energy because they radiate electromagnetic waves.

3. Who discovered the first spectral series?

a. Lyman
b. Balmer
c. Paschen
d. Pfund

Answer: (b) Balmer

Explanation: Balmer discovered the first spectral series.

4. Which of the following did Bohr use to explain his theory?

a. Quantization of angular momentum
b. Conservation of Quantum frequency
c. Conservation of Mass
d. Conservation of Linear Momentum

Answer: (a) Quantization of angular momentum

Explanation: Bohr used the quantization of angular momentum to explain his theory.

5. The significant result deduced from Rutherford's scattering experiment is that

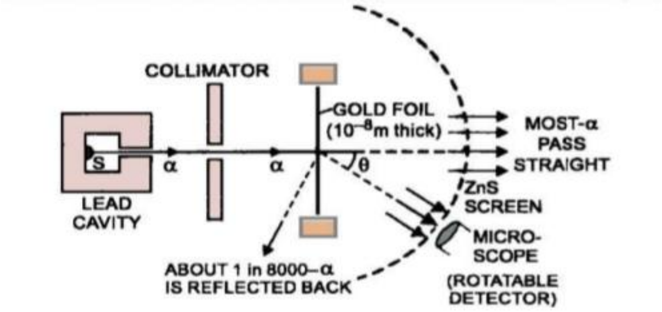
a. the whole of the positive charge is concentrated at the centre of an atom
b. there are neutrons inside the nucleus
c. α-particles are hydrogen nuclei
d. electrons are embedded in the atom

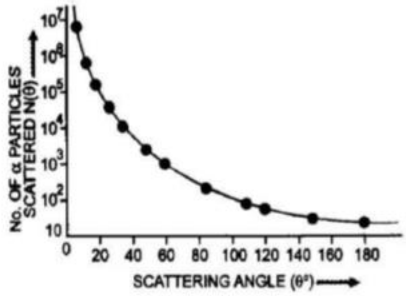
Answer: (a) the whole of the positive charge is concentrated at the centre of an atom.

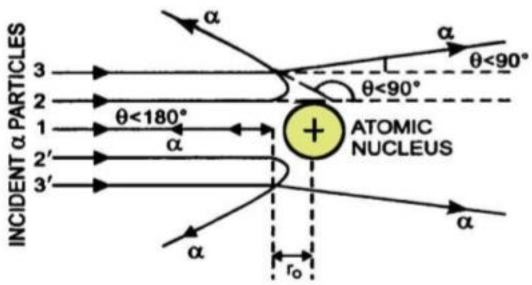
Explanation: The significant result deduced from Rutherford's scattering is that whole of the positive charge is concentrated at the centre of the atom i.e. nucleus.

Diagrams

Rutherford's α-ray scattering Experiment







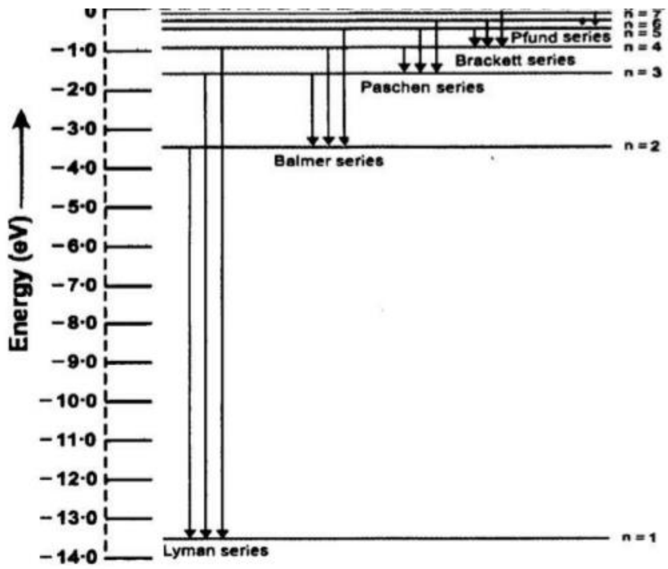
Impact Parameter (b)

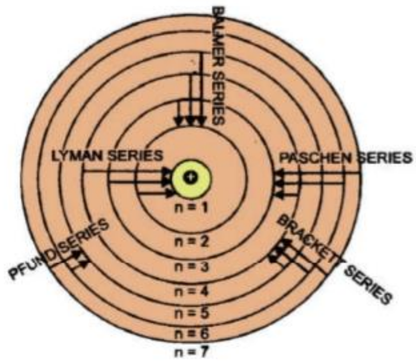
$$b = \frac{1}{4\pi\epsilon_0}\,\frac{ze^2 \cot \theta/2}{K.E.}$$

Distance of Closest Approach

$$r_0 = \frac{ze \times 2e}{4\pi\epsilon_0\left(\frac{1}{2}mv^2\right)}$$

Energy Level Diagram





$$\bar{\nu} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$$

SUMMARY

- **Thomson's Model of an Atom:**
  An atom consists of positively charged matter in which the negatively charged electrons are uniformly embedded like plums in a pudding. This model could not explain scattering of alpha-particles through thin foils and hence discarded.
- **Rutherford's Model of an Atom:**
  Geiger and Marsden in their experiment on scattering of alpha-particles found that most of the alpha-particles passed undeviated through thin foils but some of them were scattered through very large angles.
  From the results of these experiments, Rutherford proposed the following model of an atom:
  a) An atom consists of a small and massive central core in which the entire positive charge and almost the whole mass of the atom are concentrated. This core is called the nucleus.
  b) The nucleus occupies a very small space as compared to the size of the atom.
  c) The atom is surrounded by a suitable number of electros so that their total negative charge is equal to the total positive charge on the nucleus and the atom as a whole is electrically neutral.
  d) The electrons revolve around the nucleus in various orbits just as planets revolve around the sun.
  e) The centripetal force required for their revolution is provided by the electrostatic attraction between the electrons and the nucleus.
- **Draw-back of Rutherford Model:**
  This model could not explain in stability of the atom because according to classical electromagnetic theory the electron revolving around the nucleus must continuously radiate energy revolving around the nucleus must continuously radiate energy in the form of electromagnetic radiate energy in the form of electromagnetic radiation and hence it should fall into the nucleus.
- **Distance of Closest Approach:**
  When an alpha-particle of mass m and velocity v moves directly towards a nucleus of atomic number Z, its initial energy E, which is just the kinetic energy K gets completely converted into potential energy U at stopping point. This stopping point happens to be at a distance of closest approach d from the nucleus.

$$E = \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{2eZe}{d} = \frac{2Ze^2}{4\pi\varepsilon_0 d}\ d = \frac{2Ze^2}{4\pi\varepsilon_0 k}$$

Hence,

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

- **Impact Parameter:**
  a) It is defined as the perpendicular distance of the velocity of the alpha-particle from the central of the nucleus, when it is far away from the atom.
  b) The shape of the trajectory of the scattered alpha-particle depends on the impact parameter b and the nature of the potential field.
  c) Rutherford deduced the following relationship between the impact parameter b and the scattering angleθ :

$$b = \frac{1}{4\pi\varepsilon_0}.\frac{Ze^2 \cot\frac{\theta}{2}}{E}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Ze^2 \cot\frac{\theta}{2}}{\frac{1}{2}mv^2}$$

- **Quantisation or Discretisation:**
  The quantization or discretisation of a physical quantity means that it cannot very continuously to have any arbitrary value but can change only discontinuously to take certain specific values.
- **Bohr's Model for the Hydrogen Atom:**
  Basic postulates:
  a) Nuclear concept:
  An atom consists of a small massive central called nucleus around which planetary electrons revolve. The centripetal force required for their rotation is provided by the electrostatic attraction between the electrons and the nucleus.
  b) Quantum condition:
  Of all the possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in such orbits in which the angular momentum of an electron is an integral multiple of $h/2\pi$, h being Planck's constant.

$$L = mvr = \frac{nh}{2\pi}, n = 1, 2, 3....$$

  where n is called principal quantum number.
  c) Stationary orbits:
  While revolving in the permissible orbits, an electron does not radiate energy. These non-radiating orbits are called stationary orbits.
  d) Frequency condition:
  An atom can emit or absorb radiation in the form of discrete energy photons only, when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit. If E_1 and E_2 are the energies associated with these permitted orbits then the frequency ν of the emitted absorbed radiation is,

$$hv = E_2 - E_1$$

  e) Radius of the orbit of an electron in hydrogen atom is,

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

f) Kinetic energy K & electrostatic potential energy U of the electron in hydrogen atom:

$$K = \frac{1}{2}mv^2 = \frac{e_2}{8\pi\varepsilon_0 r}$$

$$U = -\frac{e^2}{4\pi\varepsilon_0 r}$$

g) Total energy E of the electron in hydrogen atom:

$$E = K + U = -\frac{e^2}{8\pi\varepsilon_0 r}$$

h) Speed of an electron in the nth orbit is,

$$v = \frac{2\pi ke^2}{nh} = \alpha\cdot\frac{c}{n} = \frac{1}{137}.\frac{c}{n}$$

Where$\alpha = \frac{2\pi ke^2}{ch}$ is fine structure constant.

i) Energy of an electron in nth orbit is,

$$E_n = \frac{2\pi^2 mk^2 Z^2 e^4}{n^2 h^2} = -\frac{13.6}{n^2}eV$$

- **Failure of Bohr's Model:**
  a) This model is applicable only to hydrogen-like atoms and fails in case of higher atoms.
  b) It could not explain the fine structure of the spectral lines in the spectrum of hydrogen atom.
- **Energy Level Diagram:**
  It is a diagram in which the energies of the different stationary states of an atom are represented by parallel horizontal lines, drawn according to some suitable energy scale.
- **Spectral Series of Hydrogen Atom:**
  Whenever an electron in hydrogen atom makes a transition from a higher energy level n_2 to a lower energy level n_1, the difference of energy appears in the form of a photon of frequency ν is given by,

$$v = \frac{2\pi^2 mk^2 e^2}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

- **Different Spectral Series of Hydrogen Atom:**
  These are as follows:
  a) Lyman Series. Here n_2 = 2, 3, 4,.....and n_1 = 1. This series lies in the ultraviolet region.
  b) Balmer Series. Here n_2 = 3, 4, 5,.... and n_1 = 2. This series lies in the visible region.
  c) Paschen Series. Here n_2 = 4, 5, 6,..... and n_1 = 3. This series lies in the infrared region.
  d) Brackett Series. Here n_2 = 5, 6, 7,..... and n_1 = 4. This series lies in the infrared region.

e) P fund Series. Here n_2 = 6, 7, 8,…. and n_1 = 5. This series lies in the infrared region.

- **Excitation Energy:**
  It is defined as the energy required by an electron of an atom to jump from its ground state to any one of its existed state.
- **Ionisation Energy**:
  It is defined as the energy required to remove an electron from an atom, i.e., the energy required to take an electron from its ground state to the outermost orbit ($n = \infty$)
- **Excitation Potential:**
  It is the accelerating potential which gives sufficient energy to a bombarding electron so to excite the target atom by raising one of its electrons from an inner to and outer orbit.
- **Ionisation Potential:**
  It is the accelerating potential which gives to bombarding electron the sufficient energy to an outer orbit.
- **De Broglie's Hypothesis:**
  The electrons having a wavelength $\lambda = h/mv$ gave an explanation for Bohr's quantised orbits by bringing in the wave particle duality. The orbits correspond to circular standing waves in which the circumference of the orbit equals a whole number of wavelengths.
- **MASER:**
  a) Maser stands for 'Microwaves Amplification by Stimulated Emission of Radiation'.
  b) It is simply a device for producing a highly intense, monochromatic coherent and collimated beam of microwaves.
- **LASER:**
  a) It stand for 'Light Amplification by Stimulated Emission of Radiation.
  b) It is a device used to produce highly intense strong monochromatic coherent and collimated beam of light.