Explanations

1. **Key idea** In case of hydrogen atom, the kinetic energy is equal to the negative of total energy and potential energy is equal to twice of the total energy.

Given, total ground state energy

$$(\text{TE}) = (-13.6\,\text{eV})$$

$\therefore$ Kinetic energy = – Total Energy

$$= -(-13.6\text{ eV}) = 13.6\text{ eV}$$

Potential energy $= 2\,(\text{TE}) = 2 \times (-13.6)$

$$= -27.2\text{ eV}$$ **(1)**

2. H_α-line of the Balmer series in the emission spectrum of hydrogen atom is obtained when an electron makes a transition from third lowest energy level to second lowest energy level. **(1)**

3. Number of spectral lines obtained due to transition of electron from n=4 (3rd excited state) to $n = 1$ (ground state) is according to formula

$$N = \frac{n(n-1)}{2}$$

$$N = \frac{(4)(4-1)}{2} = 6$$ **(1)**

4. The classical model could not explain the stability of an atom as in this atomic structure as, the electron revolving around the nucleus are accelerated and emits energy. As the result, the radius of the circular paths goes on decreasing. Ultimately electrons fall into the nucleus, which is not practical possible. **(1)**

5. For first excited state, $n = 2$.

Ground state occurs for $n = 1$

$\because \quad r_n = r_0\, n^2$

$\because \quad r \propto n^2 \qquad [\because r_0 = 0.53]$

$\Rightarrow \quad r_1/r_2 = (n_1/n_2)^2 = (2/1)^2$

$\therefore \quad r_1 : r_2 = 4 : 1$

where, r_1 and r_2 are radii corresponding to first excited state and ground state of the atom, respectively. **(1)**

6. The radius of atom whose principal quantum number is n is given by $r = n^2 r_0$

where, r_0 = radius of innermost electron orbit for hydrogen atom and $r_0 = 5.3 \times 10^{-11}$ m

For second excited state, $n = 3$

$$\therefore \quad r = 3^2 \times r_0 = 9 \times 5.3 \times 10^{-11}$$

$$r = 4.77 \times 10^{-10} \text{ m}$$ **(1)**

7. Expression for Bohr's radius in hydrogen atom

$$r_n = \frac{n^2 h^2}{4\pi^2 mKZe^2}$$

where, n = principal quantum number,

m = mass of electron,

$K = 1/4\pi\varepsilon_0 = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$,

Z = atomic number of atom = 1 and

h = Planck's constant. **(1)**

$$\Rightarrow \quad r_1 = \frac{h^2}{4\pi^2 mKe^2}$$

8. According to Bohr's quantisation condition, electrons are permitted to revolve in only those orbits in which the angular momentum of electron is an integral multiple of $\frac{h}{2\pi}$ i.e.

$$mvr = nh/2\pi \quad \text{where, } n = 1, 2, 3, \ldots$$

m, v, r are mass, speed and radius of electron and h being Planck's constant. **(1)**

9. (i) Refer to text on page 366 (Impact parameter and distance of closest approach) **(1)**

(ii) (a) For $\theta = 0°$, the impact parameter is

$$b = \frac{KZe^2 \cot\frac{\theta}{2}}{\left(\frac{1}{2}mv^2\right)}$$

$$= \frac{KZe^2 \cot 0°}{\left(\frac{1}{2}mv^2\right)} = \infty \text{ (infinity)}$$

(b) For $\theta = 180°$, its value is

$$b = \frac{KZe^2 \cot\left(\frac{180°}{2}\right)}{\left(\frac{1}{2}mv^2\right)} = 0$$

10. Refer to text on page 366 (For shortcomings of Rutherford atomic model)

For Rutherford's shortcomings overcome by Bohr's model Refer text on pages 366 and 367 (Bohr's Model of Hydrogen atom) **(2)**

11. According to Rutherford's experiment, following observations were mode.

(i) Most of the α-particles passed through the gold foil without any appreciable deflection.

(ii) Only 0.14% of incident α-particles scattered by more than 1°. But about 1 α-particle in every 8000 particles deflected by more than 90°. **(1)**

Thus, all these leads to the conclusion that atom has a lot of empty space and practically the entire mass of the atom is confined to an extremely small centered core called nucleus, whose size is of the order from 10^{-15} m to 10^{-14} m. **(1)**

12. We know that, $\lambda = \frac{h}{p} = \frac{h}{mv} \Rightarrow mv = \frac{h}{\lambda}$

$$\Rightarrow \quad mvr = \frac{hr}{\lambda} = \frac{nh}{2\pi}$$

$$\Rightarrow \quad \lambda = \frac{2\pi}{nh} \times hr = \frac{2\pi r}{n}$$

As, $\quad r \propto n^2$

$$\Rightarrow \quad \lambda \propto \frac{1}{n}(n^2) = n$$ **(1)**

Thus, we can say that, $\frac{\lambda_3}{\lambda_1} = \frac{3}{1} \Rightarrow \lambda_1 = \frac{\lambda_3}{3}$

Thus, wavelength decreases 3 times as an electron jumps from third excited state to the ground state. **(1)**

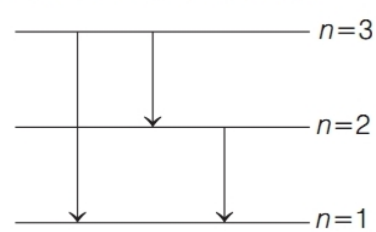
13. The energy absorbed by it is E_n

$$-13.6 + 12.5 = -1.1 \text{ eV}$$

Energy, $E_n = -\frac{13.6}{n^2} \Rightarrow n^2 = \frac{-13.6}{-1.1} = 12.36$

$$\Rightarrow \quad n \simeq 3$$ **(1)**

Thus, number of transitions = 3



(1)

14. **For Bohr's quantisation condition** Refer to Sol. 8 on page 374. **(1)**

For Brackett-series, $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$, where

$n = 5, 6, 7, \ldots$

For shortest wavelength, $n = 5$

$$\Rightarrow \quad \frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{16} - \frac{1}{25}\right)$$

$$= 1.097 \times 10^7 \times \frac{9}{16 \times 25} = 0.0246 \times 10^7$$

$\Rightarrow \quad \lambda = 40.514 \times 10^{-7} \simeq 4051 \text{ nm}$

It lies in infrared region of electromagnetic spectrum. **(1)**

15. The velocity of electron, $v_n = \dfrac{1}{n}\dfrac{Ze^2}{2h\varepsilon_0}$

Here, $Z = 1, e = 1.6 \times 10^{-19}$ C,

$\varepsilon_0 = 8.85 \times 10^{-12} \text{NC}^2\text{m}^{-2}$,

$h = 6.62 \times 10^{-34}$ J-s and $n = 2$ (in 1st excited state)

$$\Rightarrow v_2 = \frac{1 \times (1.6 \times 10^{-19})^2}{2 \times 2 \times (6.62 \times 10^{-34}) \times (8.85 \times 10^{-12})}$$

$$= 1.09 \times 10^6 \text{ m/s}$$ **(1)**

Radius of orbit, $r_2 = \dfrac{n^2 h^2 \varepsilon_0}{\pi m e^2}$

Here, $m = 9.1 \times 10^{-31}$ kg

$$\Rightarrow r_2 = \frac{(2)^2 \times (6.62 \times 10^{-34})^2 \times (8.85 \times 10^{-12})}{3.14 \times (9.1 \times 10^{-31}) \times (1.6 \times 10^{-19})^2}$$

$$= 2.12 \times 10^{-10} \text{ m}$$

Time period or orbital period,

$$T = \frac{2\pi r_2}{v_2} = \frac{2 \times 3.14 \times 2.12 \times 10^{-10}}{1.09 \times 10^6} = 1.22 \times 10^{-15} \text{ s}$$ **(1)**

16. For an electron revolving in nth orbit of radius r_n then, we have $n\lambda = 2\pi r_n$

where, λ is the wavelength of electron.

For electron orbiting in ground state $n = 1$.

$$1 \cdot \lambda = 2\pi r_n = 2\pi \times n^2 r_0$$

$$= 2\pi \times 0.5\text{Å} = \pi \text{ Å} \quad [\because r_0 = 0.5\text{Å}]$$

$$\Rightarrow \quad \lambda = 3.14 \text{ Å}$$ **(2)**

17. For electron in first excited state i.e. $n = 2$.

So, if λ be its wavelength (de-Broglie), then we have

$$n\lambda = 2\pi r_n$$

where, r_n is the radius of second orbit.

$$r_n \approx 0.5 \times n^2 \text{ (in Å)} = 0.5 \times 4 = 2 \text{ Å}$$

$$\therefore \quad 2 \times \lambda = 2 \times \pi \times 2 \text{ Å}$$

$$\Rightarrow \quad \lambda = 2\pi\text{Å} = 6.28 \text{ Å}$$ **(2)**

18. Given, energy of electron beam, $E = 12.5$ eV

Comparing with $E = hc/\lambda$, we get

$$\Rightarrow \quad E = \frac{(1240 \text{ eV-nm})}{\lambda} = 12.5 \text{eV}$$ **(1)**

$[\because hc = 1240 \text{ eV nm}]$

$\therefore$ Wavelength, $\lambda = 1240/12.5$ nm

$= 99.2 \text{ nm} = 992 \text{ Å}$

This wavelength corresponds to Lyman series of hydrogen atom. **(1)**

19. Lyman series, $n = 2, 3, 4 \ldots$ to $n = 1$

For short wavelength, $n = \infty$ to $n = 1$

$$\text{Energy, } E = \frac{12375}{\lambda(\text{Å})} = \frac{12375}{913.4} \text{ eV}$$

$$= 13.54 \text{ eV}$$ **(1)**

Also, energy of n^{th} orbit, $E = 13.54/n^2$

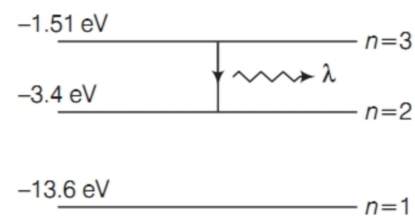
So, energy of $n = 1$, energy level $= 13.54$ eV

Energy of $n = 2$, energy level $= 13.54/2^2 = 3.387$ eV

So, short wavelength of Balmer series $= \dfrac{12375}{3.387}$

$= 3653 \text{ Å}$ **(1)**

20. Energy levels of H-atom are as shown below



Wavelength of spectral line emitted

$\Rightarrow \quad \lambda = hc/\Delta E$

Taking, $\quad hc = 1240$ eV-nm,

We have, $\quad \Delta E = -1.51 - (-3.4) = 1.89$ eV

$$\therefore \quad \lambda = \frac{1240}{1.89} \approx 656 \text{ nm}$$

This belongs to Balmer spectral series. **(2)**

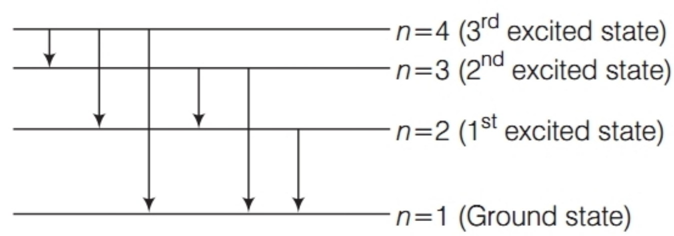
21. Frequency condition An atom can emit or absorb radiation in the form of discrete energy photons only when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit, respectively. **(1)**

$$h\nu = E_i - E_f$$

where, ν is frequency of radiation emitted, E_i and E_f are the energies associated with stationary orbits of principal quantum numbers n_i and n_f respectively (where $n_i > n_f$). **(1)**

22. Number of spectral lines obtained due to transition of electron from $n = 4$ (3rd excited state) to $n = 1$ (ground state) is

$$N = (4)(4-1)/2 = 6$$ **(1)**



These lines correspond to Lyman series. **(1)**

23. Energy of electron at $n = 2$ states is

$$E = \frac{-13.6}{n^2} = \frac{-13.6}{(2)^2} = -3.4 \text{ eV}$$ **(1)**

Now, de-Broglie wavelength of electron is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

$$= h/\sqrt{2mE} \quad [\because |K| = |E|]$$

$$= \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}}}$$

$$= \frac{6.62 \times 10^{-34}}{10 \times 10^{-25}} = 0.662 \times 10^{-9}$$

$$= 6.62 \times 10^{-10} = 6.62 \text{ Å}$$ **(1)**

24. According to de-Broglie's hypothesis, for any permissible orbit

$$2\pi r = n\lambda$$

As, $$\lambda = \frac{h}{mv}$$

$\therefore$ $$mvr = \frac{nh}{2\pi} \quad \text{...(i)}$$

(where, mvr = angular momentum of an electron and n is an integer).

Thus, the centripetal force, mv^2/r (experienced by the electron) is due to the electrostatic attraction, $\frac{KZe^2}{r^2}$

where, Z= atomic number of the atom. **(1)**

Therefore, $\frac{mv^2}{r} = \frac{KZe^2}{r^2}$

Substituting the value of v^2 from Eq. (i),

we obtain, $\frac{m}{r} \cdot \frac{n^2h^2}{4\pi^2m^2r^2} = \frac{KZe^2}{r^2}$; $\therefore$ $r = \frac{n^2h^2}{4\pi^2mKZe^2}$

The relation for the nth radius of Bohr orbit in terms of Bohr's quantization condition of orbital angular momentum $= \frac{n^2h^2}{4\pi^2mKZe^2}$ **(1)**

25. Kinetic energy of α-particle is given as

$$K = \frac{1}{4\pi\varepsilon_0}\frac{2e \cdot Ze}{d^2}$$

where, d is the distance of closest approach.

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

This is the required expression for the distance of closest approach d in terms of kinetic energy K. **(2)**

26. For Balmer series, $\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

For highest energy $n \to \infty$

$$\Rightarrow \frac{1}{\lambda_B} = \frac{R}{2^2} = \frac{R}{4} \Rightarrow \lambda_B = \frac{4}{R}$$ **(1)**

For Paschen series, $\frac{1}{\lambda_P} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$

For highest energy $n \to \infty$

$$\Rightarrow \lambda_P = \frac{9}{R} \Rightarrow \lambda_B : \lambda_P = \frac{4}{R} : \frac{9}{R} \Rightarrow 4:9$$ **(1)**

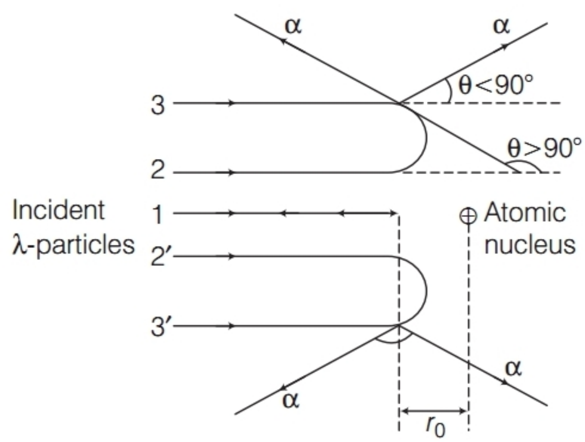
27. According to question, shortest wavelength of the spectral lines emitted in Balmer series is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] \Rightarrow \frac{1}{\lambda} = \frac{10^7}{4} \quad [\because R \approx 10^7]$$

$$\Rightarrow \lambda = \frac{4}{10^7} = 4 \times 10^{-7}$$

$$\lambda = 4000 \text{Å}$$ **(2)**

28. Trajectory of an α-particles in the Coulomb field of the target nucleus is given below as



(1)

From this experiment, the following is observed

(i) Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.

(ii) About one α-particle in every 8000 α-particles deflects by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty and at the centre of the atom, there is a heavy mass, which is most commonly known as nucleus. Thus, with the help of these observations regarding the deflection of α-particles, the size of the nucleus was predicted. **(1)**

29. According to the Bohr's theory of hydrogen atom, the angular momentum of revolving electron is given by

$$mvr = nh/2\pi \qquad \text{...(i)}$$

where, $m =$ mass of the electron, $v =$ velocity of the electron, $r =$ radius of the orbit, $h =$ Planck's constant

and $n =$ principal quantum number of the atom.

If an electron of mass m and velocity v is moving in a circular orbit of radius r, then the centripetal force is given by

$$F_c = mv^2/r \qquad \text{...(ii)}$$

(1)

Also, if the charge on the nucleus is Ze, then the force of electrostatic attraction between the nucleus and the electron will provide the necessary centripetal force.

$$\Rightarrow \quad F_c = F_e$$

$$\Rightarrow \quad \frac{mv^2}{r} = \frac{Ke^2}{r^2} \qquad [\because Z = 1]$$

$$\Rightarrow \quad r = \frac{e^2 \cdot K}{mv^2} \qquad \text{...(iii)}$$

From Eq. (i), we get $v = nh/2\pi mr$

Putting this value is Eq. (iii), we get

$$r = \frac{Ke^2 4\pi^2 m^2 r^2}{m \cdot n^2 h^2}$$

$$\Rightarrow \quad r = \frac{n^2 h^2}{Ke^2 4\pi^2 m} \Rightarrow r \propto n^2$$

(1)

30. Since, we know that for Balmer series,

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right), \; n_2 = 3, 4, 5, \ldots..$$

(1)

For shortest wavelength in Balmer series, the spectral series is given by

$$n_1 = 2, n_2 = \infty$$

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

$$\Rightarrow \quad \frac{1}{\lambda} = R \times \frac{1}{4} \Rightarrow \frac{1}{\lambda} = \frac{R}{4} \quad \Rightarrow \quad \lambda = \frac{4}{R}$$

$$\lambda = \frac{4}{1.097 \times 10^7} \quad [\because R = 1.097 \times 10^7 \text{ m}^{-1}]$$

$$\Rightarrow \quad \lambda = 3.64 \times 10^{-7} \text{ m}$$

The lines of Balmer series are found in the visible part of the spectrum. **(1)**

31. The Rutherford nuclear model of the atom describes the atom as an electrically neutral sphere consisting of a very small, massive and positively charged nucleus at the centre surrounded by the revolving electrons in their respective dynamically stable orbits. The electrostatic force of attraction F_e between the revolving electrons and the nucleus provides the requisite centripetal force (F_c) to keep them in their orbits. Thus, for a dynamically stable orbit in a hydrogen atom

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2} \qquad [\because Z = 1]$$

(1/2)

Thus, the relation between the orbit radius and the electron velocity is

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

The kinetic energy (K) and electrostatic potential energy (U) of the electron in hydrogen atom are

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

and

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

(1/2)

(The negative sign in U signifies that the electrostatic force is attractive in nature.)

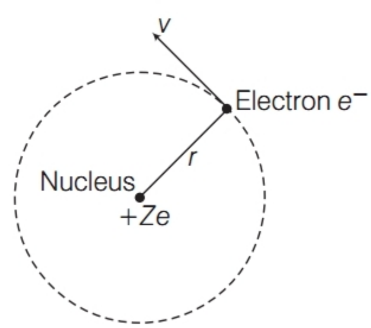
Thus, the total mechanical energy E of the electron in a hydrogen atom is

$$E = K + U = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r} = -\frac{e^2}{8\pi\varepsilon_0 r}$$

(1/2)

The total energy of the electron is negative. This implies the fact that the electron is bound to the nucleus. If E were positive, an electron will not follow a closed orbit around the nucleus and it would leave the atom. **(1/2)**

32. A hydrogen like atom consists of a tiny positively charged nucleus and an electron revolving in a stable circular orbit around the nucleus.



(1/2)

Let e, m and v be respectively the charge, mass and velocity of the electron and r the radius of the orbit.

The positive charge on the nucleus is Ze, where Z is the atomic number (in case of hydrogen atom, $Z = 1$). As, the centripetal force is provided by the electrostatic force of attraction, we have

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

or $$mv^2 = \frac{Ze^2}{4\pi\varepsilon_0 r} \quad ....(i)$$

From the first postulate of Bohr's atomic model, the angular momentum of the electron is

$$mvr = n\frac{h}{2\pi} \quad ....(ii)$$

where, n (= 1, 2, 3, ...) is **principal quantum number**. **(1/2)**

From Eqs. (i) and (ii), we get

$$r = n^2 \frac{h^2 \varepsilon_0}{\pi m Z e^2} \quad ....(iii)$$

This is the equation for the radii of the permitted orbits. According to this equation, $r_n \propto n^2$

Since, $n = 1, 2, 3, \ldots$ it follows that the radii of the permitted orbits increase in the ratio 1 : 4 : 9 : 16 : ……… from the first orbit. **(1/2)**

The radius of the first orbit $(n = 1)$ of hydrogen atom $(Z = 1)$ will be, $r_1 = h^2 \varepsilon_0 / \pi m e^2$

This is called **Bohr's radius** and its value is 0.53Å. Since $r \propto n^2$, the radius of the second orbit of hydrogen atom will be (4×0.53)Å and that of the third orbit (9×0.53) Å. **(1/2)**

33. The ionisation energy (IE) is qualitatively defined as the amount of energy required to remove the most loosely bound electron, the valence electron of an isolated gaseous atom to form a cation. Since, total energy is directly proportional to the mass of electron. **(1)**

$$E_0 = \frac{me^4}{8\varepsilon_0^2 h^2} \quad \text{i.e. } E_0 \propto m$$

So, the ionisation energy becomes 200 times on replacing an electron by a particle of mass 200 times of the electron and of same charge. **(1)**

34. (i) Given, $r_1 = 5.3 \times 10^{-11}$ m $\Rightarrow r_2 = 21.2 \times 10^{-11}$ m

$n_1 = 1$

We know that, $r \propto n^2$

$$\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \Rightarrow \frac{1}{n_2^2} = \frac{5.3 \times 10^{-11}}{21.2 \times 10^{-11}}$$

$$\Rightarrow n_2^2 = 4 \Rightarrow n_2 = 2$$ **(1)**

(ii) We know that, $E = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4$ eV **(1)**

35. *The following are the drawbacks of Rutherford's model*

(i) A moving charge in a circular path must radiate energy, because it is continuously subjected to a force. Due to this, continuous loss of energy of electrons, the radii of the orbits should be decreasing continuously. So, the concept of fixed orbit is erroneous. **(1)**

(ii) Due to this continuous decrease in radii of orbit, a charge moves over a spiral path must radiates a continuous spectrum. Hence, line emission spectrum of H-atom is not explained by Rutherford's model. **(1)**

36. Refer to Sol. 32 on pages 377 and 378. **(2)**

37. Refer to text on pages 366 and 367 [Bohr's model of hydrogen atom] **(1½)**

Refer to text on page 367.

[Important formulae related to Bohr's model of hydrogen atom (upto Eq. (iv)] **(1½)**

38. Given, energy, $E = 4.1$ MeV $= 4.1 \times 10^6 \times 1.6 \times 10^{-19}$

$= 6.56 \times 10^{-13}$ J

(i) As, kinetic energy, $E = \frac{1}{2}mv^2$

$$\Rightarrow v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2 \times 6.56 \times 10^{-13}}{1.67 \times 10^{-27}}}$$

$$= 2.8 \times 10^7 \text{ ms}^{-1}$$ **(1½)**

(ii) Distance of closest approach,

$$r_0 = K\frac{2Ze^2}{E} \quad (\because |KE| = |E|)$$

$$= 9 \times 10^9 \times \frac{2 \times 82 \times (1.6 \times 10^{-19})^2}{6.56 \times 10^{-13}}$$

$$= 576 \times 10^{-16} \text{ m}$$

39. Energy in second excited state, $E_3 = -\frac{13.6}{(3)^2}$ eV

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

Energy in ground state,

$$E_0 = -13.6 \text{ eV}$$
$$\Delta E = E_2 - E_0$$
$$= 1.51 - (-13.6)$$
$$= -1.51 + 13.6$$
$$= 12.09 \text{ eV}$$

Wavelength, $\lambda = \frac{12375}{\Delta E}$ Å $= \frac{12375}{12.09}$ Å $= 1023$ Å

40. Here, $\phi = 2$ eV, $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$E = \frac{hc}{\lambda} = hcR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \phi + \text{KE}$$

Also, KE $= eV_0$

$n_1 = 2, n_2 = n$

$$hcR\left(\frac{1}{4} - \frac{1}{n^2}\right) = 2 \times 1.6 \times 10^{-19} + 1.6 \times 10^{-19} \times 0.55$$

$$\Rightarrow 6.62\times10^{-34}\times3\times10^{8}\times1.097\times10^{7}\left(\frac{1}{4}-\frac{1}{n^2}\right)$$

$$=(3.2+0.88)\times10^{-19}$$

$$\Rightarrow 21.786\times10^{-19}\left(\frac{1}{4}-\frac{1}{n^2}\right)=4.08\times10^{-19}$$

$$\frac{1}{4}-\frac{1}{n^2}=0.187$$

$$\Rightarrow \quad n\simeq4$$ **(3)**

41. (i) Refer to diagram on page 368 (Energy level diagram). **(1)**

(ii) For largest wavelength, $n=\infty$

$$\frac{1}{\lambda_l}=R\left(\frac{1}{2^2}-\frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_l}=\frac{1.1\times10^{7}}{4}$$

$$\Rightarrow \lambda_l=\frac{4}{1.1}\times10^{-7}=3.636\times10^{-7}\text{ m}$$

$$=3636\text{ Å}$$ **(1)**

For shortest wavelength,

$$n=3$$

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

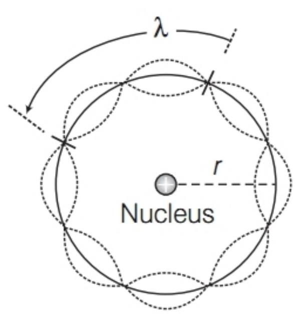
$$=1.1\times10^{7}\times\frac{5}{36}$$

$$\Rightarrow \lambda_s=\frac{36}{5.5}\times10^{-7}$$

$$=6.545\times10^{-7}\text{ m}$$

$$=6545\text{ Å}$$ **(1)**

42. (i) Bohr's second postulate defines the stable orbits. This postulate states that the electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $h/2\pi$, where h is the Planck's constant $(=6.63\times10^{-34}\text{ J - s})$.



According to de-Broglie hypothesis, wavelength of moving electron, $\lambda=\dfrac{h}{mv_n}$

whre, v_n is speed of electron revolving in nth orbit.

As, $\quad 2\pi r_n=n\lambda$ [From figure]

$$\therefore \quad 2\pi r_n=\frac{nh}{mv_n}$$

or $$mv_nr_n=\frac{nh}{2\pi}=n(h/2\pi)$$

i.e. Angular momentum of electron revolving in nth orbit must be an integral multiple of $h/2\pi$, which is the quantum condition proposed by Bohr in his second postulate. **(1½)**

(ii) We know that, energy of electron in nth orbit is

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

For $\quad n=1,\ E_1=-13.6\text{ eV}$

Similarly, for $n=4$, $E_4=-\dfrac{13.6}{(4)^2}\text{ eV}$

$\therefore$ Energy difference, $\Delta E=E_4-E_1$

$$=\left[-\frac{13.6}{16}-(-13.6)\right]\text{eV} \quad \text{... (i)}$$

Also, energy of photon is

$$\Delta E=h\nu \Rightarrow \nu=\frac{\Delta E}{h} \quad \text{... (ii)}$$

From Eqs. (i) and (ii), we get

$$\nu=\left(-\frac{13.6}{16}+13.6\right)\times\frac{1.6\times10^{-19}}{6.63\times10^{-34}}$$

$$\therefore \quad \nu=3.1\times10^{15}\text{ Hz}$$ **(1½)**

43. When an α-particle is bombarded over a gold nucleus, it is repelled by electrostatic repulsion. As a result KE of α-particle is converted into electrostatic PE. At a certain distance between the α-particle and nucleus at which the moving charge loses all its kinetic energy and becomes stationary momentarily. This distance (r) is known as distance of closest approach. In this process, all the kinetic energy (K) of moving particle is converted into potential energy. **(1)**

From the given data,

Initially, $$\frac{1}{4\pi\varepsilon_0}\cdot\frac{2e\times Ze}{r}=K \quad \text{...(i)}$$

Let r_0 be the new distance of closest approach for a twice energetic α-particle. Then, we have,

$$\frac{1}{4\pi\varepsilon_0}\times\frac{2e\times Ze}{r_0}=2K \quad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{r_0}{r}=\frac{1}{2}\Rightarrow r_0=\frac{r}{2}$$ **(1)**

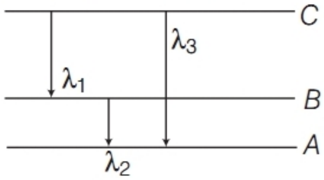
For Limitations of Rutherford Nuclear Model

Refer to Sol. 35 on page 378. **(1)**

44. Refer to Sol. 23 on page 376. **(3)**

45. (i) Refer to Sol. 42 (i) on page 379. **(1½)**

(ii) According to question,



$$E_C - E_B = hc/\lambda_1 \quad \ldots(i)$$
$$E_B - E_A = hc/\lambda_2 \quad \ldots(ii)$$
$$E_C - E_A = hc/\lambda_3 \quad \ldots(iii)$$

On adding Eqs. (i), (ii) and (iii), we get

$$E_C - E_B + E_B - E_A + E_C - E_A$$
$$2(E_C - E_A) = hc\,(1/\lambda_1 + 1/\lambda_2 + 1/\lambda_3)$$
$$2\frac{hc}{\lambda_3} = hc\left[\frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3}\right]$$
$$\Rightarrow \quad \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} \Rightarrow \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

This is the required expression. **(1½)**

46. (i) According to Bohr's postulates, in a hydrogen atom, as single electron revolves around a nucleus of charge $+e$. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is provided by coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small. **(1/2)**

So, $mv^2/r = Ke^2/r^2$ (where, $K = 1/4\pi\varepsilon_0$)

or $mv^2 = Ke^2/r \quad \ldots(i)$

where, m = mass of electron
r = radius of electronic orbit
v = velocity of electron

Again, by Bohr's second postulates

$$mvr = nh/2\pi$$

where, $n = 1, 2, 3, \ldots$ or $v = nh/2\pi mr$

Putting the value of v in Eq. (i),

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{Ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2Kme^2} \quad \ldots(ii)$$

Kinetic energy of electron,

$$E_K = \frac{1}{2}mv^2 = \frac{Ke^2}{2r} \quad \left(\because \frac{mv^2}{r} = \frac{Ke^2}{r^2}\right)$$

Using Eq. (ii), we get

$$E_K = \frac{Ke^2}{2}\,\frac{4\pi^2Kme^2}{n^2h^2} = \frac{2\pi^2K^2me^4}{n^2h^2} \quad \textbf{(1/2)}$$

Potential energy of electron,

$$E_P = -\frac{K(e)\times(e)}{r} = -\frac{Ke^2}{r}$$

Using Eq. (ii), we get

$$E_P = -Ke^2 \times \frac{4\pi^2Kme^2}{n^2h^2} = -\frac{4\pi^2K^2me^4}{n^2h^2}$$

Hence, total energy of the electron in the nth orbit

$$E = E_P + E_K = -\frac{4\pi^2K^2me^4}{n^2h^2} + \frac{2\pi^2K^2me^4}{n^2h^2}$$
$$= -\frac{2\pi^2K^2me^4}{n^2h^2} = -\frac{13.6}{n^2}\text{ eV} \quad \textbf{(1/2)}$$

This is the required expression.

(ii) Refer to Sol. 41 (ii) on page 379. **(1½)**

47. (i) Energy of electron in nth orbit of hydrogen atom.

$$E_n = \frac{-13.6}{n^2}\text{ eV} \quad \textbf{(1/2)}$$

For $n = 1 \Rightarrow E_1 = -13.6$ eV

For $n = 2 \Rightarrow E_2 = -13.6/4 = -3.4$ eV **(1/2)**

Energy required to move an electron

$$= E_2 - E_1 = -3.4 - (-13.6)$$
$$= -3.4 + 13.6 = 10.2\text{ eV} \quad \textbf{(1)}$$

(ii) (a) Kinetic energy = – (Total energy of the electron in first excited state).

$$= -(-3.4) = 3.4\text{ eV} \quad \textbf{(1/2)}$$

(b) Orbital radius in the excited state, $r = r_0n^2$

[For first excited state, $n = 2$]

$$= 4 \times 0.53 = 2.12\text{ Å} \quad \textbf{(1/2)}$$

48. Given, Bohr's radius $(r_0) = 5.3 \times 10^{-11}$ m

$$n = 3$$

Total energy of an electron in first excited state

$$= -3.4\text{ eV} \quad \textbf{(1/2)}$$

(i) Radius of orbit is given by, $r_n = n^2 r_0$

For $n = 3$ $\quad r_3 = (3)^2 \times 5.3 \times 10^{-11}$

$$\Rightarrow \quad r_3 = 47.7 \times 10^{-11} \text{ or } r_3 = 4.77 \times 10^{-10}\text{ m} \quad \textbf{(1)}$$

(ii) (a) Kinetic energy = – Total energy

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

(b) Potential energy = – 2 × Kinetic energy

$$= -2 \times 3.4 = -6.8\text{ eV} \quad \textbf{(1½)}$$

49. Refer to Sol. 46(i) on page 380. **(1½)**

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a **spectral line.**

In H-atom, when an electron jumps from the orbit n_i to orbit n_f, the wavelength of the emitted radiation is given by

$$1/\lambda = R\,(1/n_f^2 - 1/n_i^2)$$

where, R = Rydberg's constant = $1.09678 \times 10^7\ \text{m}^{-1}$ **(1/2)**

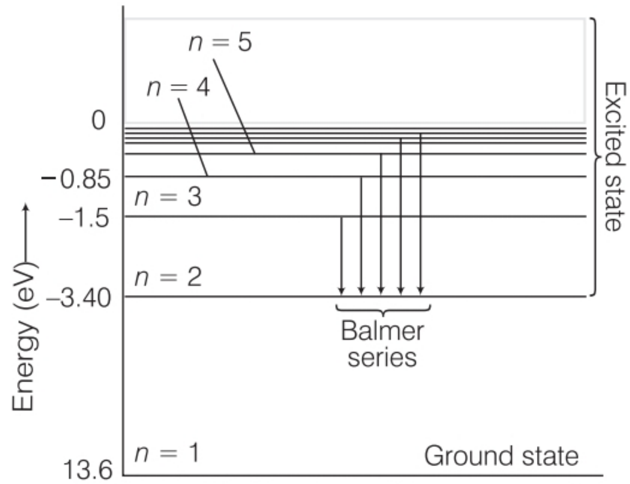
For Balmer series, $n_f = 2$ and $n_i = 3, 4, 5, \dots$

$$1/\lambda = R\,(1/2^2 - 1/n_i^2)$$

where, $n_i = 3, 4, 5, \dots$

These spectral lines lie in the visible region.

Line spectra for the Balmer series is shown below



(1)

50. According to Bohr's postulates for hydrogen atom electron revolves in a circular orbit around the heavy positively charged nucleus. These are the stationary (orbits) states of the atom.

For a particular orbit, electron moves there, so it possess both kinetic energy and potential energy.

Hence, total energy (E) of atom is sum of kinetic energy (K) and potential energy (U).

i.e. $E = K + U$ **(1/2)**

Let us assume that the nucleus has positive charge Ze. An electron moving with a constant speed v along a circle of radius r with centre at the nucleus.

Force acting on electron due to nucleus is given by, $F = Ze^2/4\pi\varepsilon_0 r^2$

The acceleration of electron $= v^2/r$ (towards the centre)

If m = mass of an electron, then from Newton's second law

$$F = m\,(v^2/r) \Rightarrow \frac{Ze^2}{4\pi\varepsilon_0 r^2} = m\left(\frac{v^2}{r}\right)$$

$$\Rightarrow \quad r = Ze^2/4\pi\varepsilon_0 mv^2 \quad \dots\text{(i)}$$

From Bohr's quantisation rules,

$$mvr = n\frac{h}{2\pi} \quad \dots\text{(ii)}$$

where, n is a positive integer. **(1/2)**

Substituting the value of r from Eq. (i) in Eq. (ii), we get

$$mv \cdot \frac{Ze^2}{4\pi\varepsilon_0 (mv^2)} = n\frac{h}{2\pi}$$

$$\Rightarrow \quad v = Ze^2/2\varepsilon_0 hn \quad \dots\text{(iii)}$$

So, kinetic energy, $K = \frac{1}{2}mv^2 = \frac{Z^2e^4}{8\varepsilon_0^2 h^2 n^2}$ ...(iv)

Potential energy of the atom,

$$U = -\frac{Ze^2}{4\pi\varepsilon_0 r} \quad \dots\text{(v)}$$

Using Eq. (iii) in Eq. (i), we get

$$r = \frac{Ze^2}{4\pi\varepsilon_0 m \frac{(Ze^2)^2}{(2\varepsilon_0 hn)^2}} = \frac{4\varepsilon_0^2 h^2 n^2}{(4\pi\varepsilon_0)\, m\, Ze^2}$$

$$\Rightarrow \quad r = \frac{\varepsilon_0 h^2 n^2}{\pi m Ze^2}$$ **(1)**

Using value of r in Eq. (v), we get

$$U = \frac{-Ze^2}{4\pi\varepsilon_0 (\varepsilon_0 h^2 n^2/\pi m Ze^2)} = \frac{-Z^2e^4 m}{4\varepsilon_0^2 h^2 n^2}$$

This implies, $U = -2K$

So, the total energy in nth energy level of hydrogen atom is

$$E = K + U = +\frac{mZ^2e^4}{8\varepsilon_0^2 h^2 n^2} - \frac{mZ^2e^4}{4\varepsilon_0^2 h^2 n^2} = -\frac{Z^2e^4 m}{8\varepsilon_0^2 h^2 n^2}$$ **(1)**

51. (i) Bohr's second postulate (quantum condition) states that the electron revolves around the nucleus in certain privileged orbit which satisfy certain quantum condition that angular momentum of an electron is an integral multiple of $h/2\pi$, where, h is Planck's constant,

i.e. $L = mvr = nh/2\pi$ **(1)**

where, m = mass of electron, v = speed of electron and r = radius of orbit of electron

$$\Rightarrow \quad 2\pi r = n(h/mv) \quad \dots\text{(i)}$$ **(1)**

Since, de-Broglie wavelength associated with an electron is given as

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad \dots\text{(ii)}$$

From Eqs.(i) and (ii), we get

∴ Circumference of electron in nth orbit $= n \times$ de-Broglie wavelength associated with electron.

(ii) Refer to Sol. 3 on page 373. **(1)**

52. Photon is emitted when electron transits from higher energy state to lower energy state, the difference of energy of the state appear in form of energy of photon.

According to Bohr's theory of hydrogen atom, energy of photon released, $E_2 - E_1 = h\nu$ **(1/2)**

Given, $E_1 = -1.15\text{ eV}$

$E_2 = -0.85\text{ eV}$

$E_2 - E_1 = -0.85 - (-1.51) = 1.51 - 0.85$

$E_2 - E_1 = 0.66\text{ eV}$ **(1/2 × 2 = 1)**

So, the wavelength of emitted spectral line,

$$\lambda = \frac{1242\text{ eV - nm}}{\text{E (in eV)}} = \frac{1242\text{ eV - nm}}{0.66\text{ eV}} = 1.88 \times 10^{-6}\text{ m}$$ **(1/2)**

As here, $\lambda = 1.88 \times 10^{-6}\text{m} \approx 18751 \times 10^{-10}\text{ m}$

The wavelength belongs to Paschen series of hydrogen spectrum. **(1)**

53. Given, $Z = 80$,

$\text{KE} = K = 8\text{ MeV} = 8 \times 10^6 \times 1.6 \times 10^{-19}\text{ J}$

$\because$ Energy, $K = \dfrac{(Ze)(2e)}{4\pi\varepsilon_0 r_0}$ **(1)**

where, r_0 = distance of closest approach.

$\Rightarrow \quad r_0 = 2Ze^2/4\pi\varepsilon_0(K)$ **(1/2)**

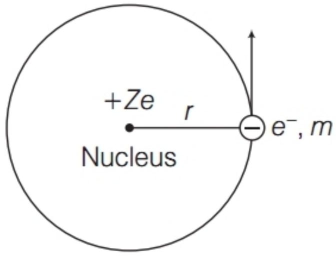
$\Rightarrow \quad r_0 = \dfrac{9 \times 10^9 \times 2 \times 80 \times (1.6 \times 10^{-19})^2}{8 \times 10^6 \times 1.6 \times 10^{-19}}$ **(1/2)**

$\Rightarrow \quad r_0 = 2.88 \times 10^{-14}\text{m}$ **(1/2)**

As, $r_0 \propto (1/K)$

If KE gets doubled, distance of closest approach reduces to half. **(1/2)**

54. Let an electron revolves around the nucleus of hydrogen atom. The necessary centripetal force is provided by electrostatic force of attraction.



$$\therefore \quad \frac{mv^2}{r} = \frac{Ke^2}{r^2} \Rightarrow r = \frac{Ke^2}{mv^2} \quad \ldots\text{(i)}$$

where, m is mass of electron and v is its speed of a circular path of radius r.

By Bohr's second postulates,

$mvr = nh/2\pi \qquad$ where, $n = 1, 2, 3\ldots$

$r = nh/2\pi mv \quad \ldots\text{(ii)}$

On comparing Eqs. (i) and (ii), we get

$$\frac{Ke^2}{mv^2} = \frac{nh}{2\pi mv} \Rightarrow v = \frac{2\pi Ke^2}{nh}$$

Substituting in Eq. (ii), we get

$$r = \frac{n^2h^2}{4\pi^2 mKe^2} \quad \ldots\text{(iii)}$$

$\Rightarrow \quad r \propto n^2$ **(1)**

Now, kinetic energy of electron

$\text{KE} = (1/2)\,mv^2 = Ke^2/2r$

Also, potential energy, $\text{PE} = -Ke^2/2r$

Energy of electron in nth orbit,

$$E_n = -\frac{Ke^2}{2r} = -\frac{Ke^2}{2} \cdot \frac{4\pi^2 mKe^2}{n^2h^2}$$

$$\Rightarrow \quad E_n = -\frac{2\pi^2 mK^2e^4}{n^2h^2} \quad \ldots\text{(iv)}$$

where, $R = \dfrac{2\pi^2 mK^2e^4}{ch^3} \Rightarrow E_n = -\dfrac{Rhc}{n^2}$ ... (v) **(1)**

where, $n = 1, 2, 3\ldots$

For $n = n_i \Rightarrow E_n \propto \dfrac{1}{n^2}$

$E_{n_i} = -\dfrac{Rhc}{n_i^2}$

and $E_{n_f} = -\dfrac{Rhc}{n_f^2}$

By Bohr's postulates, $E_{n_f} - E_{n_i} = h\nu$

$\Rightarrow \quad Rhc\,[1/n_i^2 - 1/n_f^2] = h\nu$

where, c = velocity of light

$\nu = Rc\,[1/n_i^2 - 1/n_f^2]$

This is required expression for frequency associated with photon. **(1)**

55. (i) The kinetic energy (E_K) of the electron in an orbit is equal to negative of its total energy (E).

$E_K = -E = -(-1.5) = 1.5\text{eV}$ **(1)**

(ii) The potential energy (E_P) of the electron in an orbit is equal to twice its total energy (E).

i.e. $E_P = 2E = -1.5 \times 2 = -3\text{ eV}$ **(1)**

(iii) As, a result of transition of electron from excited state to ground state.

Energy of radiation $= -1.5 - (-13.6)$

($\because$ Ground state energy of H-atom $= -13.6\text{ eV}$)

$$E = h\nu = h\frac{c}{\lambda}$$

$\Rightarrow \quad hc/\lambda = 121 \text{ eV} = \text{energy of radiation}$

$\therefore \quad \frac{1}{\lambda} = \frac{12.1 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34} \times 3 \times 10^{8}}$

$\Rightarrow \quad \lambda = 1.025 \times 10^{-7} \text{ m}$

$= 1025 \text{ Å}$ **(1)**

56. (i) Refer to Sol. 32 on page 377 and 378.

As, radius of electron's nth orbit in hydrogen atom

$$r_n = \frac{\varepsilon_0 h^2}{\pi m e^2} n^2$$

$\Rightarrow \quad r_n \propto n^2$ **(1½)**

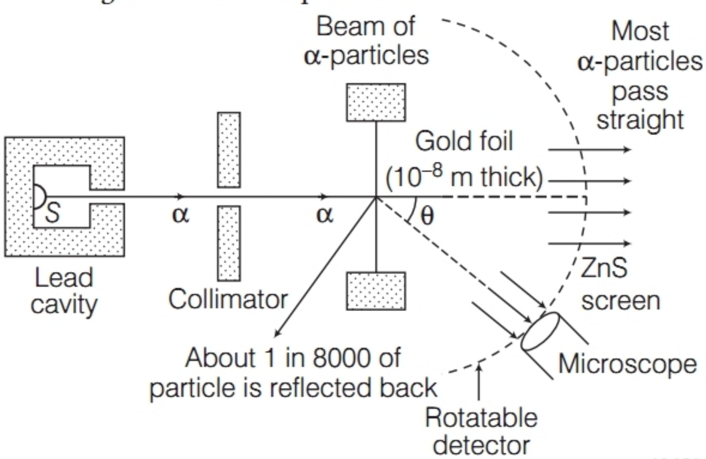
(ii) Refer to Sol. 46 (i) on page 380.

Also, the total energy of an electron belonging to nth orbit,

$$E_n = -\frac{me^2}{8\varepsilon_0^2 n^2 h^2} \Rightarrow |E_n| \propto \frac{1}{n^2}$$

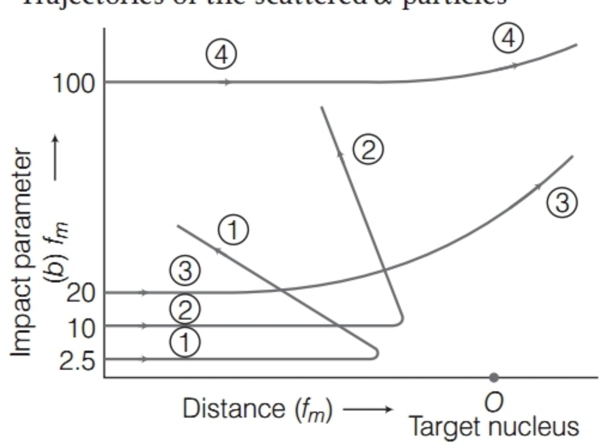
i.e. total energy of electron increases as $\frac{1}{n^2}$ **(1½)**

57. Given figure shows a schematic diagram of Geiger-Marsden experiment.



(1/2)

Trajectories of the scattered α-particles



(1/2)

Refer to Sol. 28 on page 376. **(2)**

58. *Basic assumptions of Rutherford atomic model are given below:*

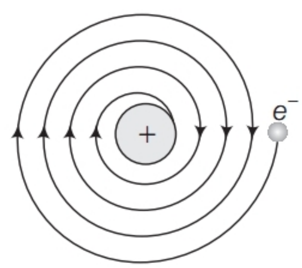
(i) Atom consists of small central core, called atomic nucleus in which whole mass and positive charge is assumed to be concentrated.

(ii) The size of the nucleus is much smaller than size of the atom.

(iii) The nucleus is surrounded by electrons. Atoms are electrically neutral as total negative charge of electrons surrounding the nucleus is equal to total positive charge on the nucleus.

(iv) Electrons revolves around the nucleus in various circular orbits and necessary centripetal force is provided by electrostatic force of attraction between positively charged nucleus and negatively charged electrons. **(2)**

Stability of atom When an electron revolves around the nucleus, then it radiates electro-magnetic energy and hence, radius of orbit of electron decreases gradually. Thus, electron revolve on spiral path of decreasing radius and finally, it should fall into nucleus, but this does not happen. Thus, Rutherford atomic model cannot account for stability of atom.



Instability of Atom

(1)

59. (i) Speed of the electron in nth orbit.

$\because$ Centripetal force of revolution is provided by electrostatic force of attraction.

$$mv^2/r = Ke^2/r^2$$

where, m = mass of electron

v = speed of electron

r = radius of orbit of the electron

$\Rightarrow \quad r = Ke^2/mv^2 \quad \ldots\text{(i)}$

Also, from Bohr's postulates,

$$mvr = \frac{nh}{2\pi} \Rightarrow r = \frac{nh}{2\pi mv} \quad \ldots\text{(ii)}$$

On comparing Eqs. (i) and (ii), we get

$$\frac{Ke^2}{mv^2} = \frac{nh}{2\pi mv}$$

$\Rightarrow \quad v = \frac{2\pi Ke^2}{nh} \quad \ldots\text{(iii)}$ **(1/2)** or $\quad v = \left(\frac{2\pi Ke^2}{ch}\right)\frac{c}{n} \qquad \left[\because K = \frac{1}{4\pi\varepsilon_0}\right]$ **(1/2)**

where, c = velocity of light or $v = \alpha \frac{c}{n}$ ...(iv)

where, $\alpha = 2\pi Ke^2/ch$ and known as fine structure constant.

Also, $\alpha = \frac{1}{137} \Rightarrow v = \frac{1}{137}\frac{c}{n}$ ...(v)

For $n = 1, v = \frac{1}{137} \times c$

In K-shell of hydrogen atom, electron revolves with $\frac{1}{137}$ times of speed of light. **(1/2)**

(ii) **For radius of nth orbit of electron** Refer to Sol. 32 on pages 377 and 378. **(1½)**

60. **Key Idea** For minimum (i.e. maximum energy) wavelength, electron will transit from ground to highest energy level and for maximum wavelength (i.e. minimum energy) electron will transit to first immediate energy state.

For Bohr's Postulates Refer to text on pages 366 and 367 (Bohr's model of hydrogen atom). **(1½)**

In second excited state, i.e. $n = 3$, the number of spectral lines obtained would be

$$N = \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = \frac{3\times 2}{2} = 3$$

$\therefore$ 3 spectral lines would be obtained.

For minimum wavelength, the transition would be from $n = 3$ to $n = 1$

$$\frac{1}{\lambda_{\min}} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8R}{9} \quad \text{...(i)}$$

For maximum wavelength, the transition would be from

$n = 3$ to $n = 2$

$$\Rightarrow \quad \frac{1}{\lambda_{\max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$= \left(\frac{9-4}{36}\right)R = \frac{5R}{36} \quad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{\lambda_{\max}}{\lambda_{\min}} = \frac{8R/9}{5R/36} = \frac{8R}{9} \times \frac{36}{5R} = \frac{32}{5}$$

$\Rightarrow \lambda_{\max} : \lambda_{\min} = 32 : 5$ **(1½)**

61. (i) Refer to text given on pages 366 and 367 (Bohr's model of hydrogen atom). **(2½)**

(ii) The wavelength of the lines in Balmer series is expressed by the formula,

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

For shortest wavelength of the spectral line emitted in Balmer series is given by

$$\frac{1}{\lambda_s} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) \qquad (\because n = \infty)$$

$$= \frac{10^7}{4} \qquad [\because R = 10^7]$$

$$\Rightarrow \quad \lambda_s = \frac{4}{10^7} = 4\times 10^{-7}\text{m} = 4000\ \text{Å}$$

For longest wavelength in Balmer series,

$$\frac{1}{\lambda_l} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \qquad (\because n = 3)$$

$$\Rightarrow \quad \frac{1}{\lambda_l} = \frac{5\times 10^7}{36}$$

or $\quad \lambda_l = 7.2\times 10^{-7}\text{m} = 7200\ \text{Å}$

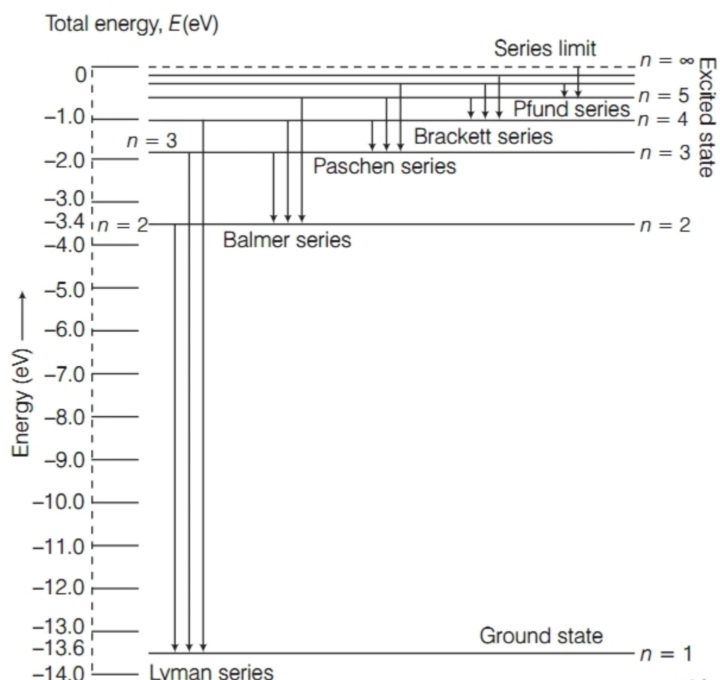
$$\therefore \quad \frac{\lambda_l}{\lambda_s} = \frac{7200}{4000} = \frac{9}{5}$$ **(2½)**

62. Refer to Sol. 54 on page 382. **(1½)**

But $\Delta E = h\nu$

$$\nu = Rc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] \text{ or } \nu = \frac{me^4}{8\varepsilon_0^2 h^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$ **(1)**

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, the Paschen, Balmer and Lyman spectral series are found.



(2½)

63. (i) Refer to Sol. 32 on pages 377 and 378 and Sol. 46 (i) on page 380.

(ii) In Balmer series,

H_α = longest wavelength (maximum), $n = \infty$

$$\therefore \quad \frac{1}{\lambda_{max}} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda_{max}} = 1.097 \times 10^7 \times \frac{1}{4}$$

$$\Rightarrow \quad \lambda_{max} = 3636 \text{ Å}$$