CBSE Test Paper-1

Class - 12 Physics (Atoms)

1. In the ground state of which model electrons are in stable equilibrium with zero net force?
   a. No model
   b. Rutherford’s model
   c. Thomson’s model
   d. Bohr model
2. A triply ionized beryllium ion Be^{3+}, (a beryllium atom with three electrons removed), behaves very much like a hydrogen atom except that the nuclear charge is four times as great. What is the ionization energy of Be^{3+} ? How does this compare to the ionization energy of the hydrogen atom?
   a. 248 eV, 16 times
   b. 218 eV, 16 times
   c. 268 eV, 16 times
   d. 218 eV, 16 times
3. Which of these statements about Bohr model hypothesis is correct?
   a. mass of electron is quantized
   b. velocity of electron is quantized
   c. angular momentum of electron is quantized
   d. radius of electron is quantized
4. Which of these statements about Bohr model hypothesis is correct?
   a. velocity of electron is quantized
   b. electron in a stable orbit emit quanta of light
   c. angular momentum is not quantized
   d. electron in a stable orbit does not radiate electromagnetic waves
5. Which of the following transitions in a hydrogen emits the photon of the highest frequency?
   a. n = 1 to n = 2
   b. n = 6 to n = 2
   c. n = 2 to n = 6

d. n = 2 to n = 1

6. Name the series of hydrogen spectrum which does not lie in the visible region.

7. Why is the classical (Rutherford) model for an atom of electron orbitting around the nucleus not able to explain the atomic structure?

8. The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of the electron in this state?

9. What is the impact parameter for scattering of α-particle by 180°?

10. An α-particle moving with initial kinetic energy K towards a nucleus of atomic number Z approaches a distance d at which it reverses its direction. Obtain the expression for the distance of closest approach d in terms of the kinetic energy of α-particle K.

11. Find the ratio between the wavelengths of the 'most energetic' spectral lines in the Balmer and Paschen series of the hydrogen spectrum.

12. The ground state energy of hydrogen atoms is -13.6 eV.

    i. Which are the potential and kinetic energy of an electron in the third excited state?
    ii. If the electron jumps to the ground state from the third excited state. Calculate the frequency of photon emitted.

13. Using the relevant Bohr's postulates, derive the expressions for the (i) speed of the electron in the nth orbit, (ii) radius of the nth orbit of the electron in hydrogen atom.

14. Which state of the triply ionized Be^{+++} has the same orbital radius as that of the ground state of hydrogen? Compare the energies of two states.

15. (a) The energy levels of an atom are as shown below. Which of them will result in the transition of a photon of wavelength 275 nm?
    (b) Which transition corresponds to emission of radiation of maximum wavelength?

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Answers

1. c. Thomson's model
   Explanation: In the atomic model proposed by J J Thomson, there are positive charges inside an atom and they neutralise the negative charge of the electron. Thus the electrons in this model are in stable equilibrium in the ground state.
2. d. 218 eV, 16 times
   Explanation: Ionization energy is energy required to remove electron from atom.
   Energy = $E_n - E_1 = -E_1$
   n = infinity, $E_n = 0$
3. c. angular momentum of electron is quantized
   Explanation: By Bohr's second postulate, the electron revolves around the nucleus only in those orbits for which the angular momentum is an integral mutiple of $\frac{h}{2\pi}$, where h is the Plancks constant. So angular momentum (L) of the orbiting electron is quantized.
4. d. electron in a stable orbit does not radiate electromagnetic waves
   Explanation: Bohr's first postulate:
   An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.
   According to this postulate, each atom has certain definite stable state in which it can exist. They do not emit energy when they are in these states. These are called the stationary states of the atom.
5. b. n = 6 to n = 2
   Explanation: According to Bohr's third postulate: When an atom makes a transition from the higher energy state n_i to the lower energy state n_f ($n_f < n_i$), the difference of energy is emitted as a photon of frequency
6. The series is named after its discoverer, Theodore Lyman, who discovered the spectral lines from 1906–1914. All the wavelengths in the Lyman series are in the

ultraviolet band.

7. Rutherford's model was unable to explain the stability of an atom. According to Rutherford's postulate, electrons revolve at a very high speed around a nucleus of an atom in a fixed orbit. Therefore, Rutherford's atomic model was not following Maxwell's theory and it was unable to explain an atom's stability.

8. The ground state energy of hydrogen atom is -13.6 eV.
   Given,total ground state energy = -13.6eV
   we know that,
   Kinetic energy = - Total Energy = - (-13.6 eV)= 13.6eV
   and
   Potential energy= 2 (TE) = 2 $\times$ (-13.6)= - 27.2 eV

9. Zero.
   Since, Impact parameter, $b=\frac{Ze^2\cot\frac{\theta}{2}}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$
   We will have $cot90^0=0$
   So impact will be zero.

10. When alpha particle approaches Nucleus, Kinetic energy of alpha particle will be converted into potential energy of the system.

    Kinetic energy of α-particle is given as,
    $K=\frac{1}{4\pi\varepsilon_0}\frac{2e.Ze}{d^2}$
    where d is the distance of closest approach.
    $d^2=\frac{2Ze^2}{4\pi\varepsilon_0K}\Rightarrow d=\sqrt{\frac{2Ze^2}{4\pi\varepsilon_0K}}$
    This is the required expression for the distance of closest approach d in terms of kinetic energy K.

11. As per the Bohr's Model, the wavelengths are given by
    $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$
    For Balmer series, $\frac{1}{\lambda_B}=R\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$
    For highest energy n $\rightarrow\infty$

$\Rightarrow \quad \frac{1}{\lambda_B}=\frac{R}{2^2}=\frac{R}{4} \Rightarrow \lambda_B=\frac{4}{R}$

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

For highest energy n $\rightarrow \infty$

$\Rightarrow \quad \lambda_p=\frac{9}{R} \Rightarrow \lambda_B: \lambda_P=\frac{4}{R}: \frac{9}{R} \Rightarrow 4: 9$

12. i. In hydrogen atom in the ground state

$E=-(K.E.)=\frac{1}{2}(P.E.)$

$\therefore$ Potential energy of electron in third excited state

$=\frac{2(E)}{(4)^2}=-\frac{2\times 13.6}{16} eV$

= -1.7 eV

$=-\frac{1}{2}(1.7)=0.85 eV$

ii. $\nu=\frac{\Delta E}{h}=\left[\frac{-13.6}{(4)^2}+\frac{13.6}{(1)^2}\right] \frac{1.6\times 10^{-19}}{6.6\times 10^{-34}}$

$=\frac{11.9\times 1.6\times 10^{-19}}{6.6\times 10^{-34}} Hz$

$\approx 2.9\times 10^{15} Hz$

13. i. Speed of the electron in nth orbit

Centnpetal force of revolution is provided by electrostatic force of attraction.

$mv^2/r = ke^2/r^2$

$r = ke^2/mv^2$.........(i)

Also, from Bohr's postulates

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

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

$\frac{ke^2}{mv^2}=\frac{nh}{2\pi mv} \Rightarrow v=\frac{2\pi ke^2}{nh}$...........(iii)

or $v=\left(\frac{2\pi Ke^2}{ch}\right) \frac{c}{n}\left[\because k=\frac{1}{4\pi\varepsilon_0}\right]$

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, $\alpha=\frac{1}{137}$

$\Rightarrow \quad v=\frac{1}{137} \frac{c}{n}$............(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.

ii. Expression for Bohr's radius in hydrogen atom

$r_n = \frac{n^2h^2}{4\pi^2 mkZe^2} \Rightarrow r_1 = \frac{n^2h^2}{4\pi^2 mke^2}$

where, n = principal quantum number,

m = mass of electron

$k = \frac{1}{4\pi\varepsilon_0}$

Z =atomic number of atom = 1 and

h =Planck's constant

14. Radius of n^{th} orbit is given by

$r = \frac{n^2h^2}{4\pi^2 mKZe^2}$ i.e. $r \propto \frac{n^2}{Z}$

For hydrogen, Z = 1, n =1 in ground state

$\therefore \frac{n^2}{Z} = \frac{1^2}{1} = 1$

For Beryleum, Z = 4, as orbital radius is same, $\frac{n^2}{Z} = 1$

$\therefore n^2 = 1 \times Z = 1 \times 4 = 4$

$n = \sqrt{4} = 2$

Hence n = 2 level of Be has same radius as n =1 level of hydrogen.

Now, energy of electron in nth orbit is $E = -\frac{2\pi^2 mK^2 Z^2 e^4}{n^2h^2}$

$\therefore E \propto \frac{Z^2}{n^2}$

$$\frac{E_{(Be)}}{E_{(H)}} = \frac{\left[\frac{Z^2}{n^2}\right]_{Be}}{\left[\frac{Z^2}{n^2}\right]_H} = \frac{\frac{16}{4}}{\frac{1}{1}} = 4$$

15. (a) For element A

Ground state energy, E_1 = -2eV

Excited state energy, E_2 = 0eV

Energy of photon emitted, E = E_2 - E_1

= 0 - (-2) = 2eV

Wavelength of photon emitted,

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

$= \frac{6.63\times10^{-34}\times3\times10^8}{2\times1.6\times10^{-19}} = \frac{19.878\times10^{-7}}{3.2}$

$= 6.211 \times 10^{-7} m$ = 621.1 nm

For element B

E_1 = -4.5 eV, E_2 = 0eV

E = 0 - (-4.5) = 4.5eV

$$\therefore \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.5\times1.6\times10^{-19}} = \frac{19.878\times10^{-7}}{7.2}$$

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

For element C

E_1 = -4.5eV, E_2 = -2eV

E = -2 - (4.5) = 2.5 eV

$$\therefore \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{2.5\times1.6\times10^{-19}} = \frac{19.878\times10^{-7}}{4}$$

$$= 4.969 \times 10^{-7}m = 496.9nm$$

For element D

E_1 = -10eV, E_2 = -2eV

E = -2 - (-10) = 8eV

$$\therefore \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{8\times1.6\times10^{-19}} = \frac{19.878\times10^{-7}}{12.8}$$

$$= 1.552 \times 10^{-7}m = 155.2nm$$

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