

CBSE Test Paper-05
Class - 12 Physics (Atoms)

1. Paschen series emission wavelengths are described by

- a. $\frac{1}{\lambda} = R \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$
- b. $\frac{1}{\lambda} = R \left(\frac{1}{4^2} - \frac{1}{n^2} \right)$
- c. $\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$
- d. $\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{3n^2} \right)$

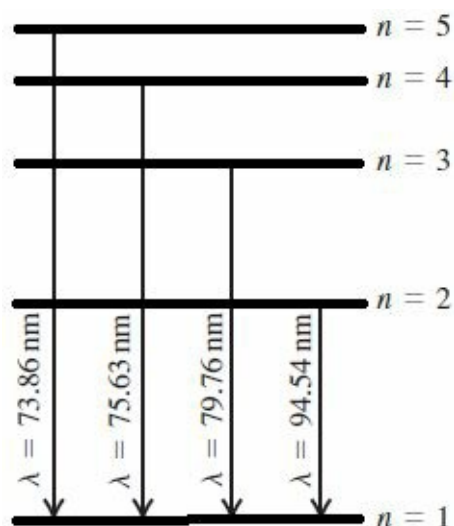
2. If an electron jumps from 1st orbit to 3rd orbit, then it will

- a. none of these
- b. remains same
- c. absorb energy
- d. release energy

3. A beam of alpha particles is incident on a target of lead. A particular alpha particle comes in “head-on” to a particular lead nucleus and stops 6.5×10^{-14} m away from the center of the nucleus. (This point is well outside the nucleus.) Assume that the lead nucleus, which has 82 protons, remains at rest. The mass of the alpha particle is 6.64×10^{-27} kg. What initial kinetic energy (in MeV) did the alpha particle have?

- a. 3.93 MeV
- b. 3.63 MeV
- c. 3.73 MeV
- d. 3.83 MeV

4. In a set of experiments on a hypothetical one-electron atom, you measure the wavelengths of the photons emitted from transitions ending in the ground state ($n = 1$) as shown in the energy-level diagram in figure. You also observe that it takes 17.50 eV to ionize this atom. What is the energy of the atom in $n = 3$?



- i. -1.94 eV
 - ii. -2.15 eV
 - iii. -1.85 eV
 - iv. -2.05 eV
5. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted?
 - a. Lyman series: 153 nm and 125 nm; Balmer series: 556 nm.
 - b. Lyman series: 133 nm and 123 nm; Balmer series: 656 nm.
 - c. Lyman series: 103 nm and 122 nm; Balmer series: 656 nm.
 - d. Lyman series: 143 nm and 122 nm; Balmer series: 646 nm.
 6. Define ionisation energy. What is its value for a hydrogen atom?
 7. Show that the radius of the orbit in hydrogen atom varies as n^2 , where n is the principal quantum number of the atom.
 8. Name the series of hydrogen atom spectrum which lies in the visible region.
 9. Using the relevant Bohr's postulates derive the expression for the radius of the electron in the n th orbit of the electron in hydrogen atom.
 10. i. In hydrogen atom, an electron undergoes transition from second excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.

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- ii. Find out the ratio of the wavelengths of the emitted radiations in the two cases.
11. (a) Using the Bohr's model calculate the speed of the electron in a hydrogen atom in the $n = 1, 2$ and 3 levels.
(b) Calculate the orbital period in each of these levels.
12. A hydrogen atom initially in the ground state absorbs a photon which excites it to the $n = 4$ level. Determine the wavelength and frequency of photon.
13. The ground state energy of hydrogen atom is -13.6eV
- 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.
14. In a Geiger-Marsden experiment, calculate the distance of the closest approach to the nucleus of $Z = 80$, when an α -particle of 8 MeV energy impinges on it before it comes to momentarily rest and reverses its direction.
How will the distance of the closest approach be affected when the kinetic energy of the α -particle is doubled?
15. If the short series limit of the Balmer series for hydrogen is $3646\overset{\circ}{\text{A}}$, calculate the atomic number of the element which gives X-ray wavelengths down to $1.0\overset{\circ}{\text{A}}$. Identify the element.

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Answers

1. a. $\frac{1}{\lambda} = R \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$

Explanation:

In this series electrons jump from any outer orbit to third orbit i.e. $n_1=3$ to $n_2=4, 5, 6$, etc.

The series lies in Infrared region.

2. c. absorb energy

Explanation: An electron in the lower state absorbs energy and moves on to higher energy state. Such electrons are said to be in an excited state.

3. b. 3.63 MeV

Explanation: By conservation of energy,

Final P. E. = Initial K. E.

Final P. E. = $\frac{1}{4\pi\epsilon_0} \frac{(2e)(Ze)}{d}$ where

d = distance of closest approach

$$e = 1.6 \times 10^{-19} \text{C}$$

$Z = 79$ for gold

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{Nm}^2/\text{C}^2$$

$$\text{Final P. E.} = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{d}$$

$$= (9 \times 10^9) (2 \times 82 \times (1.6 \times 10^{-19})^2) / 6.5 \times 10^{-14}$$

$$= 581.31 \times 10^{-15} \text{J}$$

$$= 3.63 \text{ MeV} = \text{Initial K. E.}$$

4. a. -1.94 eV

Explanation: Energy of electron in n^{th} orbit, $E_n = \frac{-17.5}{n^2} \text{eV}$

$$\text{when } n=3, E_3 = \frac{-17.5}{3^2} \text{eV} = -1.94 \text{eV}$$

5. c. Lyman series: 103 nm and 122 nm; Balmer series: 656 nm.

Explanation: Energy of hydrogen = -1.1 eV (-13.6 + 12.5) ie when 12.5 J is given to hydrogen, it absorbs energy and moves to an excited state. The electron gets

excited to $n=3$. After some duration, the electron returns to $n=1$ in the following ways,

Lyman series:

1a. From $n=3$ to $n=1$,

$$1/\lambda = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 102.6 \text{ nm}$$

1b. From $n=2$ to $n=1$,

$$1/\lambda = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 121.5 \text{ nm}$$

Balmer series

2. From $n=3$ to $n=2$,

$$1/\lambda = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 656.33 \text{ nm}$$

6. **Ionisation energy** : The amount of energy required to remove the most loosely bound electron, the valence electron, of an isolated gaseous atom to form a cation.

For hydrogen, it is 13.6eV.

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

$$mvr = \frac{nh}{2\pi} \dots\dots(i)$$

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

$$F_c = mv^2/r \dots\dots(ii)$$

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

$$\Rightarrow F_c = F_e$$

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

$$\Rightarrow r = \frac{e^2 \cdot k}{mv^2} \dots\dots(iii)$$

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

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

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

8. The Balmer series is the name given to a series of spectral emission lines of the hydrogen atom that result from electron transitions from higher levels down to the

energy level with principal quantum number 2.

Four of the Balmer lines are in the technically "visible" part of the spectrum, with wavelengths longer than 400 nm and shorter than 700 nm. Parts of the Balmer series can be seen in the solar spectrum. H-alpha is an important line used in astronomy to detect the presence of hydrogen.

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

As, the centripetal force is provided by the electrostatic force of attraction, we have

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \cdot \frac{(Ze) \times e}{r^2} \text{ or } mv^2 = \frac{Ze^2}{4\pi\epsilon_0 r} \dots\dots\dots(i)$$

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

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

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

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

$$r = n^2 \frac{h^2 \epsilon_0}{\pi m Z e^2} \dots\dots\dots(iii)$$

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, ... it follows that the radii of the permitted orbits increase in the ratio 1: 4: 9: 16:....

10. i. When an electron undergoes transition from second excited state to the first excited state it is known as Balmer series and then to the ground state is known as Lyman series.

- ii. The wavelength of the emitted radiations in the two cases , they are

For $n_2 \xrightarrow{\lambda_L} n_1$

$$\Delta E = (-3.40 + 13.6) = 10.20eV$$

$$\lambda_L = \frac{12.43 \times 10^{-7}}{10.2} = 1.218 \times 10^{-7}m$$

For $n_3 \xrightarrow{\lambda_B} n_2$

$$\Delta E = (-1.5 + 3.4) = 1.9eV$$

$$\Rightarrow \lambda_B = \frac{12.43 \times 10^{-7}}{1.9} = 6.54 \times 10^{-7}m = 6540\overset{o}{\text{A}}$$

$$\therefore \frac{\lambda_B}{\lambda_L} = \frac{6540\overset{o}{\text{A}}}{1281\overset{o}{\text{A}}} = 5.10$$

11. a. From $\nu = \frac{c}{n} \alpha$,
 where $\alpha = \frac{2\pi Ke^2}{ch}$

$$= 0.0073$$

$$v_1 = \frac{3 \times 10^8}{1} \times 0.0073 = 2.19 \times 10^6 m/s$$

$$v_2 = \frac{3 \times 10^8}{2} \times 0.0073 = 1.095 \times 10^6 m/s$$

$$v_3 = \frac{3 \times 10^8}{3} \times 0.0073 = 7.3 \times 10^5 m/s$$

b. Orbital period, $T = \frac{2\pi r}{v}$

As $r_1 = 0.53 \times 10^{-10} m$

$$T_1 = \frac{2\pi \times 0.53 \times 10^{-10}}{2.19 \times 10^6} = 1.52 \times 10^{-16} s$$

As $r_2 = 4 r_1$ and $v_2 = \frac{1}{2} v_1$

$$T_2 = 8 T_1 = 8 \times 1.52 \times 10^{-16} s = 1.216 \times 10^{-15} s$$

As $r_3 = 9 r_1$ and $v_3 = \frac{1}{3} v_1$

$$\therefore T_3 = 27 T_1 = 27 \times 1.52 \times 10^{-16} s = 4.1 \times 10^{-15} s$$

12. As, $\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$

$$\Rightarrow \frac{1}{\lambda} = 1.09 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{4^2} \right)$$

$$= 1.09 \times 10^7 \times \frac{15}{16}$$

or $\lambda = \frac{16}{1.09 \times 10^7 \times 15} = 9.8 \times 10^{-8} m$

$$\therefore \text{Frequency, } \nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{9.8 \times 10^8} = 3.06 \times 10^{15} s^{-1}$$

13. The energy of an electron in nth orbit is given by $E_n = -\frac{13.6}{n^2} eV$

i. For 3rd excite state, $n = 4$

$$\therefore E_4 = -\frac{13.6}{4^2} = -\frac{13.6}{16} = -0.85 eV$$

ii. Required energy to jump electron to the ground state from the 3rd excited state

$$E = E_4 - E_1$$

$$= -\frac{13.6}{4^2} - \left(-\frac{13.6}{1^2} \right)$$

$$= -0.85 + 13.6 = 12.75 eV$$

\therefore Wavelength of the photon emitted as

$$\lambda = \frac{hc}{E} \left(\text{As, } E = \frac{hc}{\lambda} \right)$$

$$\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{12.75 \times 1.6 \times 10^{-19}}$$

$$= \frac{19.878 \times 10^{-7}}{20.4} = 0.974 \times 10^{-7}$$

$$= 974 \overset{\circ}{\text{A}}$$

14. Given, $Z = 80$,

alpha particle energy is = K.E = $8\text{MeV} = 8 \times 10^6 \text{ eV} = 8 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$

$$\therefore \text{Energy, } K = \frac{(Ze)(2e)}{4\pi\epsilon_0 r_0}$$

we know radius of closest approach

$$\Rightarrow r_0 = 2Ze^2 / 4\pi\epsilon_0(K)$$

$$\Rightarrow r_0 = \frac{9 \times 10^9 \times 2 \times 80 \times (1.6 \times 10^{-19})^2}{8 \times 10^6 \times 1.6 \times 10^{-19}}$$

$$\Rightarrow r_0 = \frac{9 \times 10^9 \times 2 \times 80 \times (1.6 \times 10^{-19})^2}{12.8 \times 10^{-13}}$$

$$\Rightarrow r_0 = 2.88 \times 10^{-14} \text{ m}$$

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

If KE gets doubled, distance of closest approach reduces to half.

15. The short limit of the Balmer series is given by

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

$$\bar{\nu} = \frac{R}{4}$$

$$\therefore R = \frac{4}{\lambda} = \frac{4}{3646} \times 10^{10} \text{ m}^{-1}$$

Further the wavelengths of the K_α series are given by the relation

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

The maximum wave number corresponds to $n = \infty$ and, therefore, we must have

$$\bar{\nu} = \frac{1}{\lambda} = R(Z-1)^2$$

$$\text{Or } (Z-1)^2 = \frac{1}{R\lambda} = \frac{3646 \times 10^{-10}}{4 \times 1 \times 10^{-10}} = 911.5$$

$$\therefore (Z-1) = \sqrt{911.5} \cong 30.2$$

$$\text{or } Z = 31.2 \cong 31$$

Thus, the atomic number of the element concerned is 31.

The element having atomic number $Z = 31$ is Gallium.