CBSE Test Paper-04

Class - 12 Physics (Atoms)

1. In accordance with the Bohr's model, find the quantum number that characterises the earth's revolution around the sun in an orbit of radius 1.5 $\times 10^{11}$ m with orbital speed 3 $\times 10^{4}$ m/s. (Mass of earth= 6.0 $\times 10^{24}$ kg.)
   a. 2.6 $\times 10^{74}$
   b. 2.7 $\times 10^{74}$
   c. 2.9 $\times 10^{74}$
   d. 2.8 $\times 10^{74}$
2. According to 'plum pudding model' atoms on the whole are electrically neutral because
   a. the positive charge of the atom is uniformly distributed throughout the volume of the electron and the negative charge of electrons balances positive parts
   b. positive charge is concentrated at one place and negative charge is elsewhere
   c. there are equal numbers of positive charges and negatively charged electrons present in it
   d. the negative charge of the atom is uniformly distributed throughout the volume of the atom and the positively charged electrons are embedded in it
3. Balmer series emission wavelengths are described by
   a. $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$
   b. $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3n^2}\right)$
   c. $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$
   d. $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$
4. The ionization energy of 10 times ionized sodium atom is:
   a. $13.6 \times 11 eV$
   b. $13.6 \times (11)^2 eV$
   c. 13.6 / 11 eV
   d. 13.6 eV
5. 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 $\times 10^{-14}$ m away from

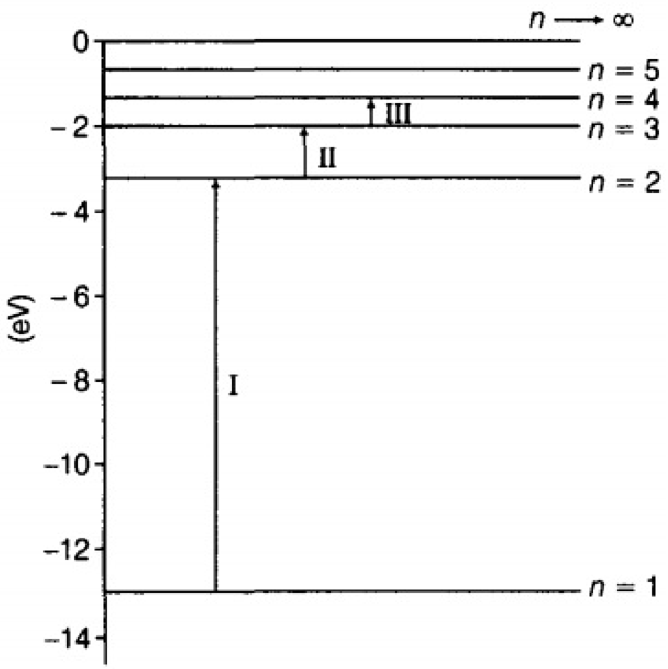
the center of the nucleus. (This point is well outside the nucleus.) Assume that the lead nucleus, which has 82 protons, remains at rest. The mass of the alpha particle is 6.64 $\times 10^{-27}$ kg. What was the initial speed of the alpha particle?

a. 1.52 $\times 10^{7}$ m/s
b. 1.62 $\times 10^{7}$ m/s
c. 1.32 $\times 10^{7}$ m/s
d. 1.42 $\times 10^{7}$ m/s

6. State Bohr's postulate of quantisation of angular momentum of the orbiting electron in hydrogen atom.

7. A 12.5 eV electron beam is used to excite a gaseous hydrogen atom at room temperature. Determine the wavelengths and the corresponding series of the lines emitted.

8. Photons with a continuous range of frequencies are made to pass through a sample of rarefied hydrogen. The transitions shown here indicate three of the spectral absorption lines in the continuous spectrum.



Identify the spectral series of the hydrogen emission spectrum to which each of these three lines correspond.

9. An electron jumps from fourth to first orbit in an atom. How many maximum number

of spectral lines can be emitted by the atom? To which series these lines correspond?

10. Define ionisation energy. How would the ionisation energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

11. Obtain an expression for the frequency of radiations emitted when a hydrogen atom de-excites from level n to level (n - 1). For large n, show that the frequency equals the classical frequency of revolution of the electron in the orbit.

12. In a Rutherford's $\alpha-$scattering experiment with thin gold foil, 8100 scintillations per minute are observed at an angle of 60°. What will be the number of scintillations per minute at an angle of 120°?

13. The wavelength of the first member of the Balmer series in hydrogen spectrum is 6563 A. What is the wavelength of the first member of Lyman series?

14. 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 - 1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?

15. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength $975\overset{o}{A}$. How many different lines are possible in the resulting spectrum? Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atom as 13.6 eV.

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Answers

1. a. 2.6×10^{74}

   Explanation: Angular momentum mvr = $\frac{nh}{2\pi}$, n=2.6 ×$10^{74.}$

2. c. there are equal numbers of positive charges and negatively charged electrons present in it

   Explanation: This atom model was proposed by JJ Thomson before the discovery of the atomic nucleus. When Thomson discovered the negative electron, he realized that atoms had to contain some positive charge material equal to the negative electrons – otherwise the atom wouldn't be electrically neutral. According to this model, the positive charge of the atom is uniformly distributed throughout the volume of the atom and the negatively charged electrons were embedded in it like seeds in a watermelon.

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

   Explanation: In this series electron jumps from any outer orbit to second orbiti.e. n1 = 2 to n2 =3, 4, 5, etc

4. b. $13.6 \times (11)^2 eV$

   Explanation: Hydrogenic atoms are the atoms consisting of a nucleus with positve charge (+Ze) and a single electron, where Z is the proton number. Examples are hydrogen atom, singly ionised helium, etc. During ionisation, an atom or a molecule acquires a negative or positive charge by gaining or losing electrons and form ions. When Sodium is ionized 10 times, it becomes like a hydrogen atom. The proton number of Sodium is Z=11. Hence ionisation energy of 10 times ionised sodium atom is $13.6 \times (11)^2 eV$

5. c. $1.32 \times 10^7 \mathrm{m/s}$

   Explanation: K.E. = 1/2 mv^2

   Initial K.E. = 3.63 MeV = 5.82×10^{-13} J

   m = 6.4×10^{-27} kg

   $5.82 \times 10^{-13} = \frac{1}{2} \times 6.4 \times 10^{-27} \times v^2$

$$\Rightarrow v^2 = \frac{2\times5.82\times10^{-13}}{6.4\times10^{-27}}$$
$$\Rightarrow v = \sqrt{1.818 \times 10^{14}}$$
$$\Rightarrow v = 1.32 \times 10^7 m/s$$

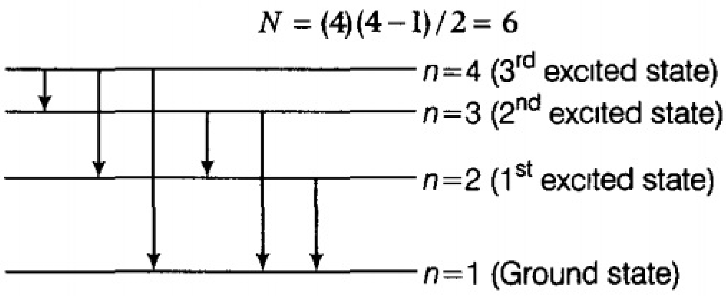
6. According to Bohr's quantisation rule, electrons revolve in only those orbits in which the angular momentum of electron is an multiple of $\frac{h}{2\pi}$ i.e,
   $mvr = nh/2\pi$ where n = 1, 2, 3 ,4...........
   m, v. r are mass, speed and radius of electron and h is Planck's constant.
7. The wavelength of series emitted during transition is given by the formula:
   hc / E = λ
   E = 12.5 eV
   hc = 1240 eV
   Therefore wavelength of emitted series is:
   λ = 1240 / 12.5 = 99.2 nm
   This belongs to the Lyman series of Bohr's Hydrogen Spectrum.
   therefore , The wavelength of emitted series is 99.2 nm and this belongs to the Lyman series of Bohr's Hydrogen Spectrum.
8. By observing question, we can infer following results
   i. Layman series is obtained when an electron jumps from the first orbit to any outer orbit.
      So, first spectrum represent Lyman series because, in this spectrum, the electron jumps from n = 1 to n=2.
   ii. Balmer series is obtained when an electron jumps from the second orbit to any outer orbit.
      So, second spectrum represent Balmer series because, in this spectrum, the electron jumps from n=2 to n=3
   iii. Paschen series is obtained when an electron jumps from the third orbit to any outer orbit.
      So, third spectrum represent paschen series because, in this spectrum, the electron jumps from n=3 to n=4
9. The maximum number of spectral lines obtained when electron on fourth orbital jumps to ground state can be found as:
   $n_2 - n_1 = 4 - 1 = 3$
   The electron can make a transition from

4→3, 4→2, 4→1 = 3

3→2, 3→1 = 2

2→1 = 1

Total Number of spectral lines = 3 + 2 + 1 = 6 lines.



These line corresponds to Paschen series.

10. The ionisation energy (IE) is defined as the amount of energy required to remove the most loosely bound electron i.e; valence electron of an isolated gaseous atom to form a cation.

ionisation energy is given by,

$E_0 = \frac{me^4}{8E_0^2 h^2}$

i.e. $E_0 \propto m$

ionisation energy is directly proportional to mass.

The ionisation energy becomes 200 times on replacing an electron by a particle of mass 200 times of the electron and of same charge.

11. The frequency ν of the emitted radiation when a hydrogen atom de-excites from level n to level (n - 1)is

E = hv = E_2 - E_1

$\nu = \frac{1}{2}\frac{mc^2\alpha^2}{h}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ where $\alpha = \frac{2\pi Ke^2}{ch}$ find structure constant

$\nu = \frac{1}{2}\frac{mc^2\alpha^2}{h}\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{mc^2\alpha^2}{2h}\left[\frac{n^2-(n-1)^2}{n^2(n-1)^2}\right]$

$= \frac{mc^2\alpha^2[(n+n-1)(n-n+1)]}{2h\ n^2(n-1)^2}$

$\nu = \frac{mc^2\alpha^2\,(2n-1)}{2h\ n^2(n-1)^2}$

For large n, (2n - 1) = 2n, and (n - 1) = n

$\nu = \frac{mc^2\alpha^2 \cdot 2n}{2h\ n^2 \cdot n^2} = \frac{mc^2\alpha^2}{h\ n^3}$

Putting $\alpha = \frac{2\pi Ke^2}{ch}$ we get $\nu = \frac{mc^2}{h\ m^3} \cdot \frac{4\pi^2 K^2 e^4}{c^2 h^2}$

$\nu = \frac{4\pi^2 m K^2 e^4}{n^3 h^3}$

In Bohr's atom model velocity of electron in nth orbit is $v = \frac{n\ h}{2\pi mr}$ and radius of nth orbit is $r = \frac{n^2 h^2}{4\pi^2 m K e^2} (\because Z = 1)$

Frequency of revolution of electron $\nu = \frac{v}{2\pi r} = \frac{nh}{2\pi mr}\left(\frac{4\pi^2 mKe^2}{2\pi . n^2 h^2}\right)$

$\nu = \frac{Ke^2}{nh \cdot r} = \frac{Ke^2}{nh}\left(\frac{4\pi^2 mKe^2}{n^2 h^2}\right)$

$\nu = \frac{4\pi^2 m K^2 e^4}{n^3 h^3}$

which is the same as (i)

Hence for large values of n, classical frequency of revolution of electron in nth orbit is the same as the frequency of radiation emitted when hydrogen atom de-excites from level (n) to level (n - 1).

12. n_1 (number of scintillations per minute at an angle 60°) = 8100

n_2 (number of scintillations per minute at an angle 120°) = ?

The scattering in the Rutherford's experiment is proportional to $\cot^4 \frac{\phi}{2}$

$\frac{n_2}{n_1} = \frac{\cot^4 \frac{\phi_2}{2}}{\cot^4 \frac{\phi_1}{2}}$ or

Hence, $\frac{n_2}{n_1} = \frac{\cot^4\left(\frac{120^\circ}{2}\right)}{\cot^4\left(\frac{60^\circ}{2}\right)} = \frac{\cot^4 60^\circ}{\cot^4 30^\circ}\left(\frac{\frac{1}{\sqrt{3}}}{\sqrt{3}}\right)^4 = \frac{1}{81}$

$\Rightarrow n_2 = \frac{1}{81} \times n_1 = \frac{1}{81} \times 8100$ = 100

13. Balmer series

$\frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$

$\frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3R}{4}$

$\frac{\lambda_2}{\lambda_1} = \frac{4}{3R} \times \frac{5R}{36} = \frac{20}{108} = \frac{5}{27}$

$\lambda_2 = \frac{5}{27} \times \lambda_1 = \frac{5}{27} \times 6523 = 1215 \overset{o}{A}$

14. According to Bohr's theory of hydrogen energy of photon released, $E_2 - E_1 = hv$

Given, $E_1 = -1.51$ eV

$E_2 = -0.85$

$E_2 - E_1 = -0.85 - (-1.51) = 1.51 - 0.85 = 0.66$ eV

So, the wavelength of emitted spectral line,

$\lambda = \frac{1242\mathrm{eV-nm}}{\mathrm{E(ineV)}} = \frac{1242\mathrm{eV-nm}}{0.66\mathrm{eV}} = 1.88 \times 10^{-6}\mathrm{m}$

The wavelength belongs to Paschen series of hydrogen spectrum

15. Wavelength of the monochromatic radiation, λ= 975 $\mathring{A}$

Ionization energy for hydrogen atom = 13.6 eV.

The energy of monochromatic radiation of wavelength

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

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{975\times10^{-10}\times1.6\times10^{-9}}\mathrm{eV}$

= 12.75 eV

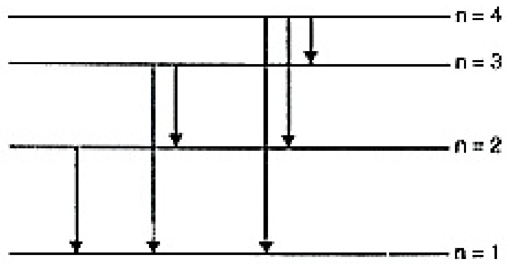
$\therefore 12.75 = 13.6\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$

$\frac{1}{n^2} = 1 - \frac{12.75}{13.6}$

$= \frac{0.85}{13.6} = \frac{1}{16}$

$\therefore \quad n = 4$

Number of lines possible in the resultant spectrum = 6, as shown in figure.



The longest wavelength will be emitted for transition from 4th orbit to 3rd orbit with an energy.

$E_{n_2} - E_{n_1} = E_0 Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Atomic Number, Z = 1

$E_{4\to3} = 13.6\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$

$= 13.6\left(\frac{1}{9} - \frac{1}{16}\right)$

$E_{4\to3} = 13.6 \times \frac{7}{144}\mathrm{eV}$

$= 13.6 \times \frac{7}{144} \times 1.6 \times 10^{-19}\mathrm{J}$

The longest wavelength, $\lambda = \frac{\mathrm{hc}}{\mathrm{E}_{4\to3}}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}\times144}{13.6\times7\times1.6\times10^{-19}}\mathrm{m}$

$\lambda = 1.88 \times 10^{-6}\mathrm{m} = 18800\mathring{A}$