CBSE Test Paper-02
Class - 12 Physics (Atoms)

1. According to Bohr's theory, the moment of momentum of an electron revolving in second orbit of hydrogen atom will be:
   a. $\frac{2h}{\pi}$
   b. $\frac{h}{\pi}$
   c. $2\pi rh$
   d. πh
2. The ground state energy of hydrogen atom is –13.6 eV. Find the orbital radius and velocity of the electron in a hydrogen atom
   a. 5.6 $\times 10^{-11}$ m, 2.5 $\times 10^{6}$ m/s
   b. 5.4 $\times 10^{-11}$ m, 2.3 $\times 10^{6}$ m/s
   c. 5.3 $\times 10^{-11}$ m, 2.2 $\times 10^{6}$ m/s
   d. 5.5 $\times 10^{-11}$ m, 2.4 $\times 10^{6}$ m/s
3. A hydrogen atom is in a state with energy -1.51 eV. In the Bohr model, what is the angular momentum of the electron in the atom, with respect to an axis at the nucleus?
   a. 3.56 $\times 10^{-34}$kgm^{2} /s
   b. 3.16 $\times 10^{-34}$kgm^{2} /s
   c. 3.76 $\times 10^{-34}$kgm^{2} /s
   d. 3.36 $\times 10^{-34}$kgm^{2} /s
4. The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?
   a. 13.6 eV, –27.2 eV
   b. 14.6 eV, –27.2 eV
   c. 14.6 eV, –29.2 eV
   d. 13.1 eV, –29.2 eV
5. The ratio of longest wavelength and the shortest wavelength observed in the Balmer series in the emission spectrum of hydrogen is:
   a. 2.8
   b. 1.8
   c. 3.8

d. 4.8

6. Name the series of hydrogen spectrum lying in the infrared region.

7. Can a hydrogen atom absorb a photon having energy more than 13.6 eV?

8. When is H_α - line of the Balmer series in the emission spectrum of hydrogen atom obtained?

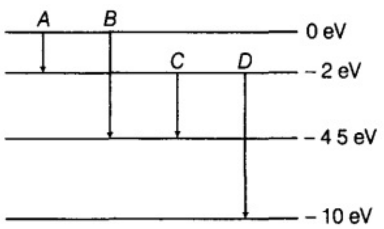
9. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 A. Calculate the short wavelength limit for Balmer series of the hydrogen spectrum.

10. 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?

11. A difference of 2.3 eV separates two energy levels in an atom. What is the frequency of radiation emitted when the atom make a transition from the upper level to the lower level?

12. Calculate the radius of the first orbit of hydrogen atom. Show that the velocity of electron in the first orbit is $\frac{1}{137}$ times the velocity of light.

13. i. The energy levels of an atom are as shown in figure below. Which of them will result in the transition of a photon of wavelength 275 nm?



ii. Which transition corresponds to emission of radiation of minimum wavelength?

14. The Rydberg constant for hydrogen is 10967700 m^{-1}. Calculate the short and long wavelength limits of Lyman series.

15. Determine the speed of electron in n = 3 orbit of He^+. Is the non-relativistic approximation valid?

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Answers

1. b. $\frac{h}{\pi}$

   Explanation: Angular momentum (L) is an integral multiple of $h/2\pi$ where h is the Planck's constant i.e. $L = nh/2\pi$.

   For second orbital electron, n=2, so

   $L = \frac{2h}{2\pi}$,

   $L = \frac{h}{\pi}$

2. c. 5.3 $\times 10^{-11}$ m, 2.2 $\times 10^{6}$ m/s

   Explanation: Energy of electron, $E = -\frac{e^2}{8\pi\varepsilon_0 r}$

   E = -13.6 eV = -2.2 x 10 $^{-18}$ J

   Radius, $r = \frac{-e^2}{2(4\pi\varepsilon_0)E} = \frac{(9\times10^9)(1.6\times10^{-19})^2}{2(-2.2\times10^{-18})} = 5.3 \times 10^{-11} m$

   Velocity, $v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}} = \frac{(1.6\times10^{-19})}{\sqrt{4\times3.14\times(8.85\times10^{-12})\times(9.1\times10^{-31})\times(5.3\times10^{-11})}}$

   $= 2.2 \times 10^6 m/s$

3. b. $3.16 \times 10^{-34}\text{kgm}^2/\text{s}$

   Explanation: Energy in nth orbit = -13.6 / n^2

   n^2 = -13.6/-1.51eV = 9

   n=3

   Angular momentum, L = nh/2pi

   L = (3 $\times$ 6.626 $\times$ 10 $^{-34}$) / 2 $\times$ 3.14

   L = 3.16 $\times$ 10 $^{-34}$ kgm^2/sec

4. a. 13.6 eV, –27.2 eV

   Explanation: Total energy, E = -13.6 eV

   Since sum of energies is constant so

   K.E = 13.6 eV (-E)

   and P.E = -27.2 eV (2 K.E)

5. b. 1.8

   Explanation: Longest wavelength in this series = 656.3 nm

Shortest wavelenth = 364.6 nm

Ratio = 656.3 / 364.6 = 1.8

6. The series of lines in the hydrogen spectrum which lie in the infrared region are:
    - Paschen series : Near infrared region
    - Brackett series : Infrared region
    - Pfund series : Far infrared region
    - Humphrey series : Very far infrared region

7. Yes, it can absorb. But the atom would be ionized.

8. 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 .i.e; From n=3 to n=2

9. Lyman series, n = 2, 3, 4... to n= 1
   For short wavelength, n =∞ to n = 1
   we know that ,
   $E = \frac{12375}{\lambda(\overset{o}{A})} = \frac{12375}{9134}\text{eV} = 13.54\text{eV}$

   Energy of n^{th} orbit, E = $13.54/n^2$
   So, energy of n = 1, energy level = 13.54eV
   Energy of n = 2, energy level= $13.54/2^2$ = 3.387 eV
   So, short wavelength of Balmer series = $\frac{12375}{3.387}$ = 3653 $\overset{o}{A}$

10. 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, 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
    $F_c = F_e$
    $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2}$ [Z = 1]
    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

$K=\frac{1}{2} m v^{2}=\frac{e^{2}}{8 \pi \varepsilon_{0} r}$

and $U=-\frac{e^{2}}{4 \pi \varepsilon_{0} r}$

(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

$E=K+U=\frac{e^{2}}{8 \pi \varepsilon_{0} r}-\frac{e^{2}}{4 \pi \varepsilon_{0} r}=-\frac{e^{2}}{8 \pi \varepsilon_{0} r}$

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 dosed orbit around the nucleus and it would leave the atom.

11. $E_2 - E_1$ = 2.3 eV $=2.3 \times 1.6 \times 10^{-19} J$

$\nu=\frac{E_{2}-E_{1}}{h}$

$\Rightarrow \nu=\frac{2.3 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$

or $\nu=\frac{3.68 \times 10^{15}}{6.6}$

$=0.557 \times 10^{15} Hz$

$=5.6 \times 10^{14} Hz$

12. Since, $r=\frac{n^{2} h^{2}}{4 \pi^{2} m K Z e^{2}}$

Using n = 1 for 1 st orbit

$h=6.6 \times 10^{-34} Js$

$m=9 \times 10^{-31} kg$

$K=9 \times 10^{9}\ Nm^{2} C^{-2}$

Z = 1 for hydrogen, $e=1.6 \times 10^{-19}$ coulomb

We get, $r=0.53 \times 10^{-10} m$

Also, $\nu=\frac{2 \pi K e^{2}}{n h}=\frac{c}{n}\left(\frac{2 \pi K e^{2}}{c h}\right)$

$=\frac{c}{1} \times 2 \times \frac{22}{7} \times \frac{9 \times 10^{9} \times\left(1.6 \times 10^{-19}\right)^{2}}{3 \times 10^{8} \times 6.6 \times 10^{-34}}$

$v=\frac{1}{137} c$

13. i. Given, wavelength of the photon, $\lambda=275 nm$

Energy of photon is given by,

$E=h \nu$

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

$E = \frac{1242 \text{ eV}}{\lambda(\text{in nm})} = 4.5\text{eV}$

From fig. this transition corresponds to B since for transition B.

E = 0 - (- 4.5eV) = 4.5eV

ii. Energy of Photon Emitted, E = hc/$\lambda \propto 1/\lambda$

For minimum wavelength of emission, the energy is maximum.

Transition D, for which the energy emission is maximum, corresponds to the emission of radiation of minimum wavelength.

14. For Lyman series, the wave number is given by

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

For the short wavelength limit $(\lambda - \lambda_S), n = \infty$

or $\overline{\nu}_S = \frac{1}{\lambda_S} = R_H\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R_H$

$\therefore \lambda_S = \frac{1}{R_H} = \frac{1}{10967700}m$

$= 9.116 \times 10^{-8}m = 911.6\overset{o}{A}$

For long wavelength limit $(\lambda = \lambda_L)\, n = 2$

$\therefore \overline{\nu}_L = \frac{1}{\lambda_L} = R_H\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3}{4}R_H$

$\therefore \lambda_L = \frac{4}{3R_H}$

$= \frac{4}{3} \times 911.6\overset{o}{A} = 1215\overset{o}{A}$

15. The speed of electron in nth orbit is given by

$v = \frac{2\pi KZe^2}{nh}$

For He, Z = 2, n = 3

$v = \frac{2\pi K2e^2}{3h}$

$= \frac{4\times3.14\times9\times10^9(1.6\times10^{-19})^2}{3\times6.6\times10^{-34}}$

$v = 1.46 \times 10^6 m/s$

Now, $\frac{v}{c} = \frac{1.46\times10^6}{3\times10^8}$ = 0.048

which is much less than 1.

Hence non-relativistic approximation is true.