Chapter 12

Atoms

Solutions (Set-1)

Very Short Answer Type Questions:

1. What is the maximum number of emission lines falling in Lyman series when an excited electron of a H-atom in n = 6 drops to the ground state?

Sol. 15

2. Out of Thomson, Rutherford and Bohr, whose model has uniform mass distribution?

Sol. Thomson

3. Whose atomic model is analogous to solar system?

Sol. Rutherford

4. According to Bohr's postulate of quantisation, angular momentum of electron, in stable orbit of Hydrogen, should be an integral multiple of ________.

Sol. $\dfrac{h}{2\pi}$

5. For P-fund series, frequency of photon is minimum for transition of electron from n = _______,to n = _______.

Sol. 6 to 5

6. Total energy ________ and kinetic energy ________ while moving from ground state to excited state.

Sol. Increases, decreases

7. What is the dimension of Rydberg constant?

Sol. $[L^{-1}]$

8. Radius of orbit is directly proportional to n^2 (True/False).

Sol. True

9. What is the value of ionisation energy for an electron having kinetic energy 3.4 eV?

Sol. 3.4 eV

10. Foil of which element, was used in alpha particle scattering experiment?

Sol. Gold

Short Answer Type Questions :

11. Calculate velocity of electron in second orbit of hydrogen atom.

Sol. $v_n = \dfrac{e^2}{2\varepsilon_0 hn}$

$$v_2 = \frac{(1.6\times10^{-19})^2}{2(8.854\times10^{-12})(6.626\times10^{-34})\times2}$$

$= 1.095 \times 10^6$ m/s

12. Calculate radius of third orbit of hydrogen atom.

Sol. $r_n = \left(\dfrac{\varepsilon_0 h^2}{\pi me^2}\right)n^2$

$$= \frac{(8.854\times10^{-12})\times(6.626\times10^{-34})^2\times3^2}{3.14\times(9.1\times10^{-31})(1.67\times10^{-19})^2}$$

$= 4.77$Å

13. Calculate time period of an electron moving in third orbit of hydrogen atom.

Sol. $T_n = \left(\dfrac{4\varepsilon_0^2 h^3}{me^4}\right)n^3$

$$= \frac{3\times(8.85\times10^{-12})^2(6.626\times10^{-34})^3\times9}{(9.1\times10^{-31})(1.67\times10^{-19})^4}$$

$= 1.359 \times 10^{-15}$ seconds

14. Calculate area enclosed by the fifth stable orbit of hydrogen atom.

Sol. Area = πr^2

$= 3.14 \times (0.53 \times 5^2)^2 \times 10^{-20}$ m^2

$= 5.51 \times 10^{-18}$ m^2

15. Calculate frequency of electron in second orbit.

Sol. $f_n = \dfrac{me^4}{4\varepsilon_0^2 h^3 n^3}$

$$= \frac{(9.1\times10^{-31})(1.67\times10^{-19})^4}{4\times(8.85\times10^{-12})^2(6.63\times10^{-34})^3\times8}$$

$= 8.32 \times 10^{14}$ Hz

16. Calculate total energy of electron in its second excited state in hydrogen atom.

Sol. $E_n = -\dfrac{13.6}{n^2}$eV

For second excited state, $n = 3$

$E = -\dfrac{13.6}{9}$eV

$= -1.51$ eV

17. Calculate the Rydberg constant if is known that wavelength difference between the first lines of Balmer and Lyman series is equal to 5312 Å.

Sol. For first line of Balmer series

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

$$\therefore \quad \lambda_B = \frac{36}{5R}$$

For first line of Lyman series

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

$$\lambda_L = \frac{4}{3R}$$

$$\lambda_B - \lambda_L = \frac{36}{5R} - \frac{4}{3R}$$

$$= \frac{88}{15R}$$

$$= 5312 \times 10^{-10}\,\text{m}$$

$\Rightarrow \quad R = 1.104 \times 10^7\ \text{m}^{-1}$

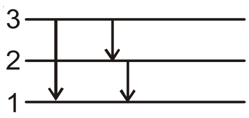
18. The ionisation energy of hydrogen atom is 13.6 eV. It is exposed to electromagnetic waves of 1028 Å and gives out induced radiations. Find the wavelength of these induced radiations.

Sol. Energy of incident photon

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1028 \times 10^{-10} \times 1.6 \times 10^{-19}}\,\text{eV}$$

E = 12.1 eV

Electron can be excited upto third energy state.



$$\frac{1}{\lambda_1} = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}, \lambda_1 = \frac{4}{3R}$$

$$\frac{1}{\lambda_2} = R\left[1 - \frac{1}{9}\right] = \frac{8R}{9}, \lambda_2 = \frac{9}{8R}$$

$$\frac{1}{\lambda_3} = R\left[\frac{1}{4} - \frac{1}{9}\right] - \frac{5R}{36}, \lambda_3 = \frac{36}{5R}$$

19. In a hydrogen, three electronic transitions are described as shown is figure

x : n = 4, to n = 1

y : n = 5 to n = 2

z = n = 6 to n = 3

(i) The photons emitted in which transition x, y or z will have shortest wavelength?

(ii) For which transition will the electron experience the largest change in orbit radius?

Sol. (i) As energy difference is maximum in x, therefore in this transition, emitted photon will have shortest wavelength.

(ii) As radius is directly proportional to n^2, therefore in z, electron will experience largest change in radius.

20. What do you mean by atomic spectra? How did Bohr explained hydrogen spectra?

Sol. Atomic spectra: When a body is heated, it emits electromagnetic radiations of various components of different wavelengths, which is called atomic spectra.

21. A series of lines in the spectrum of atomic hydrogen has wavelengths of emitted photons 656.46 nm, 486.27 nm, 434.17 nm. What is the wavelength of next line of this series?

Sol. Clearly, the given wavelengths are corresponding to the first, second and third line of Balmer series.

Wavelength corresponding to fourth line

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{6^2}\right)$$

$\Rightarrow$ $\lambda = 410.2$ nm

22. Calculate the kinetic energy, potential energy and total energy associated with first orbit hydrogen atom (in joules).

Sol. $E = -13.6$ eV

$= -13.6 \times 1.67 \times 10^{-19}$ J

$= -2.27 \times 10^{-18}$ J

Potential energy $= 2E$

$= -4.54 \times 10^{-18}$ J

Kinetic energy $= -E$

$= 2.27 \times 10^{-18}$ J

23. Calculate the frequency, energy and wavelength of radiations corresponding to spectral lines of second lowest frequency of Balmer series in spectra of H-atom.

Sol. For second lowest frequency

$n_f = 2$ and $n_i = 4$

$\therefore$ $\Delta E = E_4 - E_2 = -\{0.85 - (-3.4)\}$ eV

$\Delta E = 2.55$ eV

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

$$= \frac{(6.63\times10^{-34})(3\times10^{8})}{2.55\times(1.67\times10^{-19})} = 4.67 \times 10^{-7} \text{ m}$$

$\lambda = 4670$ Å

$$\text{Frequency } f = \frac{c}{\lambda}$$

$$= \frac{3\times10^{8}}{4.67\times10^{-7}} = 6.42 \times 10^{14} \text{ Hz}$$

24. The potential energy of an electron in hydrogen atom is –3.02 eV. Find the area enclosed by the orbit of this atom.

Sol. Total energy = $\frac{U}{2}$ = –1.51 eV

∴ $n = 3$

∴ Area enclosed by third orbit

$A = 3.14 \times (0.53 \times 10^{-10} \times 3^2)^2$

$A = 7.14 \times 10^{-19}\ m^2$

25. Write two differences in Thomson's atomic model and Rutherford's nuclear model.

Sol. Differences in Thomson's model and Rutherford's model.

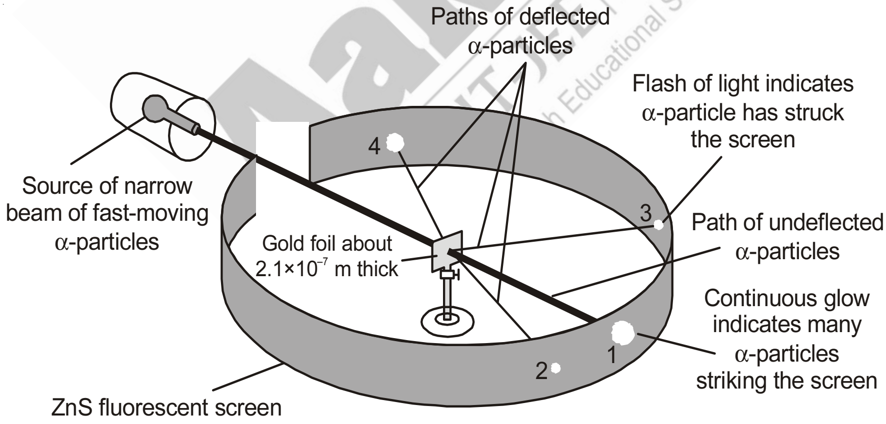
(i) In Thomson's model, mass was uniformly distributed whereas in Rutherford's model mass was concentrated in the nucleus.

(ii) In Thomson's model, electrons were embedded in between protons, whereas in Rutherford's model electrons were orbiting around nucleus.

26. Give the details of experiment performed by Geiger and Marsden.

Sol. H. Geiger and E. Marsden performed an experiment on α-particles scattering, in 1911, as suggested by Ernst Rutherford.

In this experiment, they used a beam of 5.5 MeV, α-particles obtained from $^{214}_{83}Bi$ radioactive source and bombarded it on a thin gold foil. Scattering of α-particles was observed through a rotatable detector made up of zinc sulphide screen and a microscope.



Schematic arrangement of the Geiger Marsden experiment

Observations

1. Most of the α-particles passed through the foil without any deviation.
2. About 0.14% of the incident α-particles scattered by more than 1°.
3. Deflection of more than 90° was observed in about 0.0125% of the incident α-particles.

Inferences

1. Most of the space in an atom is unoccupied as about 99.86% α-particles passed without deviation.

2. There must be an extremely small region of concentrated positive charge at the centre of an atom. This small region is called nucleus. The scattering of α-particles is due to encounter between the α-particle and the nucleus of the atom.

3. The nucleus of the atom is so massive as compared with the α-particles that it remains at rest during the encounter, whereas electrons, owing to their little mass, cannot appreciably deflect the far more massive α-particles.

4. Electrons revolve around the nucleus in orbits just like planets revolve around the sun.

5. When an α-particle strikes the metal foil, it can penetrate the outer electron cloud and approaches the nucleus closely. It then moves under the action of coulomb's force of repulsion, and its path is hyperbola with the nucleus as the external forces.

27. Explain, why model proposed by Rutherford was not stable.

Sol. Rutherford's model was not stable on the basis of classical theory of electromagnetism according to which a charged particle when accelerated, emits photon.

28. What do you mean by stable orbits?

Sol. Orbits in which angular momentum of electron is integral multiple of $\frac{h}{2\pi}$ is called stable orbits.

29. Give details of Bohr's third postulate.

Sol. An electron can make a transition from its stable orbit to another lower orbit stable. While doing so, a photon is emitted whose energy is equal to the energy difference between the initial and final states.

Therefore, the energy of photon is given by,

$$h\nu = E_i - E_f$$

where E_i and E_f are the energies of the initial and final states. ($E_i > E_f$)

30. Rutherford's nuclear model was analogous to solar system, but why it is unstable while later is stable?

Sol. In atom, electrons orbit around the nucleus due to electrostatic force of attraction, whereas in planet being neutral, move in elliptical orbit due to gravitational force of attraction. Rutherford's model was unstable on the basis of classical theory of electromagnetism.

Long Answer Type Questions :

31. Derive expression for kinetic energy, potential energy and total energy of electron moving in n^{th} orbit in hydrogen like atom.

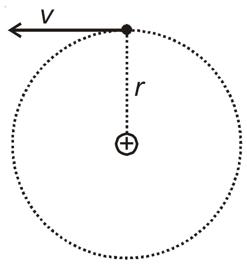
Sol. (1) Kinetic energy of n^{th} orbit electron in hydrogen atom :

$$KE = \frac{1}{2}mv^2$$

$$= \frac{1}{2}(mv^2) \quad \text{... (i)}$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{... (ii)}$$



Putting value of mv^2 in equation (i)

$$KE = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}\right) = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$$

$$KE = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{\left(\frac{\varepsilon_0 h^2}{\pi me^2}\right)n^2}$$

$$KE = \frac{me^4}{8\varepsilon_0^2 h^2}\frac{1}{n^2}$$

(2) Potential energy:

$$PE = \frac{1}{4\pi\varepsilon_0}\frac{(e)(-e)}{r}$$

$$PE = -\frac{me^4}{4\varepsilon_0^2 h^2}\frac{1}{n^2}$$

(3) Total energy of electron in n^{th} orbit :

$$TE = KE + PE = \frac{me^4}{8\varepsilon_0^2 h^2}\frac{1}{n^2} - \frac{me^4}{4\varepsilon_0^2 h^2}\frac{1}{n^2}$$

$$TE = -\frac{me^4}{8\varepsilon_0^2 h^2}\frac{1}{n^2}$$

32. What is atomic spectra? Describe spectral lines in Hydrogen.

Sol. From Bohr's third postulate, a photon is emitted when an atoms makes a transition from higher energy state to lower-energy state.

Let electron jumps from higher energy state n_i to lower energy state n_f and the frequency of emitted photon is ν, then

$$h\nu = E_i - E_f$$

$$h\nu = \frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\Rightarrow \quad \nu = \frac{me^4}{8\varepsilon_0^2 h^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

But $\nu = \frac{c}{\lambda}$

$$\Rightarrow \quad \frac{1}{\lambda} = \frac{me^4}{8\varepsilon_0^2 ch^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

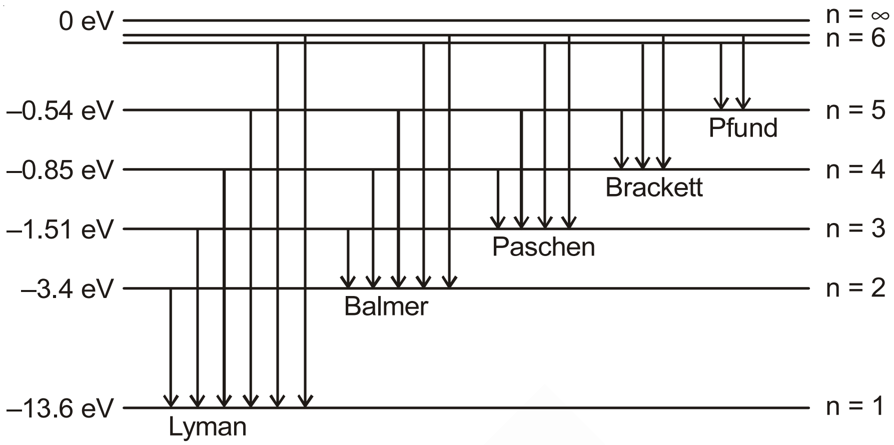
The term $\frac{me^4}{8\varepsilon_0^2 ch^3}$ is taken as Rydberg constant R

$$R = \frac{me^4}{8\varepsilon_0^2 ch^3} = 1.03 \times 10^7 \text{ m}^{-1}$$

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

As n_i and n_f are integers, so light fo discrete frequencies is emitted.

Various spectral series are shown in spectral diagram.



33. Calculate the orbital velocity and the orbital radius of the electron in a hydrogen like atom if 10.2 eV energy is required to separate a hydrogen like atom into a proton and an electron situated in first excited state.

Sol. $r = \dfrac{e^2}{8\pi\varepsilon_0 E} = \dfrac{(9\times10^9)(1.6\times10^{-19})^2}{(2)(-10.2\times1.6\times10^{-19})}$ m

$$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}} = \frac{(1.6\times10^{-19})}{\sqrt{\left(\dfrac{1}{9\times10^9}\right)\times(9.1\times10^{-31})\times c}}$$

34. Write down the Bohr's three postulates and hence derive $E_n = -\dfrac{13.6}{n^2}$ eV. (where symbols have their usual meaning)

Sol. Bohr's three postulates are :

Postulate I: An electron in an atom could revolve in certain stable orbits without emitting radiant energy. These stable orbits are called the stationary states of the atom.

Postulate II: An electron can revolve around the nucleus in an atom only in those stable orbits whose angular momentum is the integral multiple of $\dfrac{h}{2\pi}$ (where h is Planck's constant).

$\therefore \quad L(\text{angular momentum}) = \dfrac{nh}{2\pi}$ (n = 1, 2, 3 .....)

Postulate III: An electron can make a transition from its higher stable orbit to lower stable orbit. While doing so, a photon is emitted whose energy is equal to the energy difference between states.

i.e., energy of photon is given by,

$h\nu = E_i - E_f$

where E_i and E_f are the energies of the initial and final states.

Total energy of electron in n^{th} orbit

$$E_n = k + M = -k = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}$$

Putting value of $r = \dfrac{n^2\varepsilon_0 h^2}{\pi m e^2}$

$$\therefore \quad E_n = -\frac{me^4}{8x^2\varepsilon_0^2 h^2} = -\left(\frac{13.6}{n^2}\text{eV}\right)$$

35. Derive Rydberg's constant $R = \dfrac{me^4}{8\varepsilon_0^2 hc^3}$ on the basis of Bohr's postulates.

Sol. From Bohr's third postulate, a photon is emitted when an atom makes a transition from higher energy state to lower energy state.

Let an electron jumps from higher energy state n_i to lower energy state n_f and the frequency of emitted photon is ν, then

$$h\nu = E_i - E_f$$

$$= \frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\Rightarrow \quad \nu = \frac{me^4}{8\varepsilon_0^2 h^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Putting $\nu = \dfrac{c}{\lambda}$

$$\Rightarrow \quad \frac{1}{\lambda} = \frac{me^4}{8\varepsilon_0^2 ch^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

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

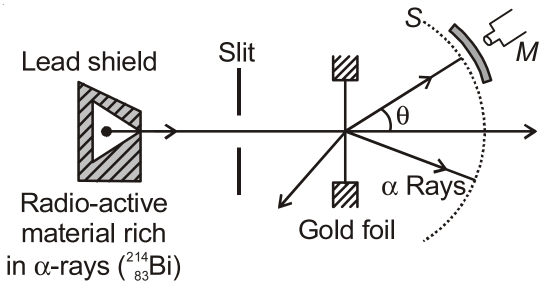
where $R = \dfrac{me^4}{8\varepsilon_0^2 ch^3}$ = Rydberg's constant

$= 1.03 \times 10^7 \text{ m}^{-1}$

36. Describe the experiment according to which Ernst Rutherford proposed the planetary model of the atom.

Sol. Geiger and Marsden performed an experiment on α-particles scattering as suggested by Rutherford.

Experimental setup:



They placed a thin metal gold foil of thickness 2.1×10^{-7} m in path of α-particles coming from radioactive substance $^{214}_{83}\text{Bi}$.

A fluorescent screen *S*, backed by a microscope *M* was placed behind the foil.

The particles, passing thorugh the foil were scattered through wide range of angles. These particles produce scintillations on screen *S*.

37. What is Bohr's second postulate of quantisation? Who explained Bohr's second postulate? Describe his explanation.

Sol. Bohr's Postulate II: An electron can revolve around the nucleus in an atom only in those stable orbits whose angular momentum is the integral multiple of $\dfrac{h}{2\pi}$.

i.e., $L = mv_n r_n = \left(\dfrac{nh}{2\pi}\right)$

de-Broglie explained Bohr's second postulate with his wave nature of particle.

electron revolves in that orbit whose circumference is integral multiple of wavelength associated.

i.e., $2\pi r_n = n\lambda$

But $\lambda = \dfrac{h}{mv}$

$\Rightarrow \quad 2\pi r_n = \dfrac{h}{mv_n}$

$\Rightarrow \quad mv_n r_n = \dfrac{nh}{2\pi}$

38. An electron in an atom revolves around the nucleus in orbit of radius 0.53Å. Calculate the equivalents magnetic moment if the frequency of revolution of electron is 6.8×10^9 MHz.

Sol. 0.96×10^{-23} Am^2

39. An electron in an atom revolves around the nucleus in an orbit of radius 0.5Å. Calculate the frequency of revolution of electron if the equivalent magnetic moment is 1.25×10^{-23} Am^2.

Sol. $r = 0.5$ Å

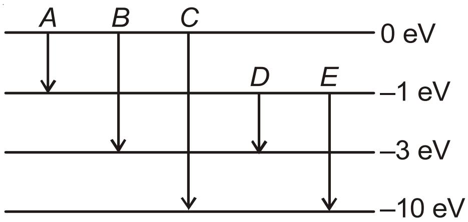
M = dipole moment = 1.25×10^{-23} Am^2

But $M = \left(\dfrac{e}{T}\right)\pi r^2 = (ef)\pi r^2$

$$\Rightarrow \quad f = \text{frequency} = \frac{M}{e\pi r^2} = \frac{1.25\times10^{-23}}{1.6\times10^{-19}\times3.14\times0.5\times0.5\times10^{-20}}$$

$= 10^{16}$ Hz (Approx.)

40. The energy levels of an atom of element are shown in the following diagram. Which one of the level transitions, will result in the emission of photons of wavelength 620 nm? Support your answer with mathematical calculations.



Sol. Energy of photon of wavelength

$\lambda = 620$ nm

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{620\times10^{-9}\times1.6\times10^{-19}}\text{ eV}$$

$= 2$ eV (Approx.)

$(\Delta E)_D = -1 - (-3)$

$= 2$ eV

$\therefore$ D transition will correspond to emission of photon of wavelength 620 nm.

41. In a hydrogen atom, an electron of charge e revolves in an orbit of radius r with a speed v. Prove that magnetic moment associated with the electron is given by $\frac{evr}{2}$.

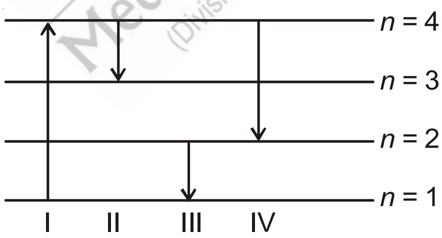
Sol. Magnetic moment associated with orbital motion of electron

$M = i\times\pi r^2$

$= \frac{e}{T}.\pi r^2$

But $T = \frac{2\pi r}{v}$ $= M = \frac{e.\pi r^2}{\frac{2\pi r}{v}} = \frac{evr}{2}$

42. The energy levels for an electron in a certain hydrogen like atom is shown below. Which transition shown represents the emission of a photon with most energy? Explain.



Sol. Energy loss is maximum in IV transition of electron.

$\therefore$ In IV transition, photon of maximum energy will be emitted.

43. A hydrogen atom is in excited state of principal quantum number (n). It emits a photon of wavelength (λ), when it returns to the ground state. Find the value of n.

Sol. Total energy of electron in n^{th} state

$$E_n = -\frac{me^4}{8\varepsilon_0^2n^2h^2}$$

Total energy of electron in ground state

$$E_1 = -\frac{me^4}{8\varepsilon_0^2 h^2}$$

But, $E_n - E_1 = \frac{hc}{\lambda}$

$$\Rightarrow \quad \frac{me^4}{8\varepsilon_0^2 h^2}\left[1 - \frac{1}{n^2}\right] = \frac{hc}{\lambda}$$

$$\Rightarrow \quad 1 - \frac{1}{n^2} = \frac{hc}{\lambda}\frac{8\varepsilon_0^2 h^2}{me^4}$$

$$\frac{1}{n^2} = 1 - \frac{8\varepsilon_0^2 h^3 c}{me^4\lambda} = \frac{me^4\lambda - 8\varepsilon_0^2 h^3 c}{me^4\lambda}$$

$$n = \sqrt{\left(\frac{me^4\lambda}{me^4\lambda - 8\varepsilon_0^2 h^3 c}\right)}$$

44. An α-particle of kinetic energy 5.5 MeV is approaching directly towards gold nucleus (Z = 79). Estimate closest approach.

Sol. For closest approach

$$K_\alpha = \frac{1}{4\pi\varepsilon_0}\left(\frac{2Ze^2}{r_0}\right)$$

$$\Rightarrow \quad r_0 = \frac{1}{4\pi\varepsilon_0}\left(\frac{2Ze^2}{k\alpha}\right)$$

$$= \frac{9\times10^9 \times 2\times 79\times(1.6\times10^{-19})^2}{5\times5.5\times10^6\times(1.6\times10^{-19})}\,\text{m}$$

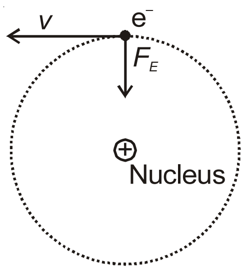
$$= 4.14 \times 10^{-14}\ \text{m}$$

45. Using Bohr's postulate prove that Bohr radius $a_0 = \frac{h^2\varepsilon_0}{\pi me^2}$. (Where symbols have their usual meaning)

Sol. Electric force of attraction provides necessary centripetal force.

$$F_C = F_E$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \qquad \text{... (i)}$$



From Bohr's quantisation condition

$$mvr = \frac{nh}{2\pi} \qquad \text{... (ii)}$$

Putting the value of *v* from equation (ii) and equation (i)

$$v = \frac{nh}{2\pi mr}$$

$$\therefore \quad m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\Rightarrow \quad r = \frac{n^2\varepsilon_0 h^2}{\pi me^2}$$

$$r = n^2 a_0$$

where $a_0 = \dfrac{h^2\varepsilon_0}{\pi me^2} = 0.53\,\text{Å}$

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Chapter 12

Atoms

Solutions (Set-2)

1. Thickness of the foil of gold used in α-particle scattering experiment is

(1) 2.1×10^{-7} m (2) 3.5×10^{-5} m (3) 2.1×10^{-9} m (4) 3.5×10^{-6} m

Sol. Answer (1)

Refer theory

2. The scattering α-particles were observed through a rotatable detector consisting of a screen of

(1) Copper sulphide (2) Zinc sulphide (3) Graphite (4) Gold

Sol. Answer (2)

Refer theory

3. In Rutherford's experiment, scattering of more than 1° was observed in

(1) 14% of the incident α-particles (2) About 0.14% of the incident α-particles

(3) About 1.4% of the incident α-particles (4) About 0.014% of the incident α-particles

Sol. Answer (2)

Refer theory

4. In scattering experiment, α-particles were deflected by

(1) Repulsive force of electrons (2) Repulsive force of gold nucleus

(3) Attractive force of electrons (4) Attractive force of gold nucleus

Sol. Answer (2)

Refer theory

5. Energy of the beam of α-particles used by Geiger and Marsden in scattering experiment is

(1) 2.2 MeV (2) 4.2 MeV (3) 5.1 MeV (4) 5.5 MeV

Sol. Answer (4)

Refer theory

6. Source of α-particles used in scattering experiment was

(1) $_{82}Bi^{216}$ (2) $_{81}Bi^{216}$ (3) $_{81}Bi^{214}$ (4) $^{214}_{83}Bi$

Sol. Answer (4)

Refer theory

7. In scattering experiment, find the distance of closest approach, if a 6 MeV α-particle is used

(1) 3.2×10^{-16} m (2) 2×10^{-14} m (3) 4.6×10^{-15} m (4) 3.2×10^{-15} m

Sol. Answer (2)

At distance of closest approach

$$PE = K_{initial}$$

Where $K_{initial}$ is initial kinetic energy.

$$\therefore \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{2e^2}{d} = 6\times1.6\times10^{-13}\text{ J}$$

$$\Rightarrow d = \frac{9\times10^9\times(1.6\times10^{-19})^2\times2}{6\times1.6\times10^{-13}}\text{m}$$

$$= 4.8 \times 10^{-16}\text{ m}$$

8. An α-particle colliding with one of the electrons in a gold atom looses

(1) Most of its momentum (2) About $\frac{1}{3}$rd of its momentum

(3) Little of its energy (4) Most of its energy

Sol. Answer (3)

Mass of an electron is negligible as compared to α-particle.

9. The angular momentum of an electron in a hydrogen atom is proportional to (where n is principal quantum number)

(1) n (2) n^2 (3) n^3 (4) $\sqrt{n}$

Sol. Answer (1)

$$mvr = \frac{nh}{2\pi}$$

10. When an electron in hydrogen atom is taken from fourth excited state to ground state

(1) Both kinetic energy and potential energy increases

(2) Both kinetic energy and potential energy decreases

(3) Kinetic energy will increase while potential energy will decrease

(4) Kinetic energy will decrease while potential energy will increase.

Sol. Answer (3)

Both U & $K \propto \frac{1}{n^2}$, potential energy is negative whereas kinetic energy is positive.

11. What should be the angular momentum of an electron in Bohr's hydrogen atom whose energy is –0.544 eV?

(1) $\frac{h}{\pi}$ (2) $\frac{3h}{2\pi}$ (3) $\frac{5h}{2\pi}$ (4) $\frac{2h}{2\pi}$

Sol. Answer (3)

$E = -0.544 \text{ eV} = -\frac{13.6}{25}\text{eV}$

$\therefore \quad n=5$

$\Rightarrow L = \frac{5h}{2\pi}$

12. The energies of three conservative energy levels L_3, L_2 and L_1 of hydrogen atom are E_0, $\frac{4E_0}{9}$ and $\frac{E_0}{4}$ respectively. A photon of wavelength λ is emitted for a transition L_3 to L_1. What will be the wavelength of emission for transition L_2 to L_1?

(1) $\frac{16\lambda}{31}$ (2) $\frac{27\lambda}{7}$ (3) $\frac{19}{20}\lambda$ (4) λ

Sol. Answer (2)

13. Ground state energy of H-atom is –13.6 eV. The energy needed to ionise H-atom from its second excited state is

(1) 1.51 eV (2) 3.4 eV (3) 13.6 eV (4) 12.1 eV

Sol. Answer (1)

For second excited state, n = 3

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

14. The product of angular speed and tangential speed of electron in n^{th} orbit of hydrogen atom is

(1) Directly proportional to n^2 (2) Directly proportional to n^3

(3) Inversely proportional to n^4 (4) Independent of n

Sol. Answer (3)

$v_n\omega_n = \frac{v_n^2}{r_n}$

$v_n\omega_n \propto \frac{1}{n^2 \times n^2}$

$v_n\omega_n \propto \frac{1}{n^4}$

15. The speed of an electron in the 4^{th} orbit of hydrogen atom is

(1) c (2) $\frac{c}{137}$ (3) $\frac{c}{2192}$ (4) $\frac{c}{548}$

Sol. Answer (4)

$$V = \frac{v_0}{n} = \frac{c}{137 \times 4} = \frac{c}{548}$$

16. What should be the ratio of minimum to maximum wavelength of radiation emitted by transition of an electron to ground state of Bohr's hydrogen atom?

(1) $\frac{3}{4}$ (2) $\frac{1}{4}$ (3) $\frac{1}{8}$ (4) $\frac{3}{8}$

Sol. Answer (1)

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

For minimum wavelength, $n = \infty$

For maximum wavelength, $n = 2$

$$\therefore \quad \frac{\lambda_{min}}{\lambda_{max}} = \left(\frac{\frac{1}{1^2} - \frac{1}{2^2}}{\frac{1}{1^2} - \frac{1}{(\infty)^2}}\right) = \frac{3}{4}$$

17. The ratio of energies of hydrogen atom in its first excited state to third excited state is

(1) $\frac{1}{4}$ (2) $\frac{4}{1}$ (3) $\frac{3}{4}$ (4) $\frac{4}{3}$

Sol. Answer (2)

For first excited state, $n = 2$

$$\therefore \quad E = \frac{E_0}{2^2}$$

For third excited state, $n = 4$

$$\therefore \quad E = \frac{E_0}{4^2}$$

$$\therefore \quad \text{Ratio} = \frac{16}{4} = \frac{4}{1}$$

18. When an electron is excited to n^{th} energy state in hydrogen, the possible number of spectral lines emitted are

(1) n (2) $2n$ (3) $\frac{n^2 - n}{2}$ (4) $\frac{n^2 + n}{2}$

Sol. Answer (3)

19. The energy of hydrogen atom in its ground state is –13.6 eV, the energy of the level corresponding to $n = 7$ is

(1) –0.544 eV (2) –5.40 eV (3) –0.85 eV (4) –0.28 eV

Sol. Answer (4)

20. In which transition of a hydrogen atom, photons of lowest frequency are emitted?

(1) $n = 4$ to $n = 3$ (2) $n = 4$ to $n = 2$ (3) $n = 2$ to $n = 1$ (4) $n = 3$ to $n = 1$

Sol. Answer (1)

Frequency is directly proportional to energy difference of the orbital and energy difference is minimum for 4 to 3 transition.

21. Total energy of an electron in the hydrogen atom in the ground state is –13.6 eV. The potential energy of this electron is

(1) 13.6 eV (2) 0 (3) –27.2 eV (4) –13.6 eV

Sol. Answer (3)

Potential energy = 2(total energy)

22. Using Bohr's formula for energy quantization, the ionisation potential of first excited state of hydrogen atom is

(1) 13.6 V (2) 3.4 V (3) 2.6 V (4) 1.51 V

Sol. Answer (2)

Ionization potential = $\dfrac{\text{Ionisation energy}}{e}$

23. Which of the following cannot be the value of ionisation energy for a hydrogen atom?

(1) 0.85 eV (2) 3.4 eV (3) 1.51 eV (4) 0.27 eV

Sol. Answer (4)

24. Which series of hydrogen atom lie in infrared region?

(1) Lyman (2) Balmer

(3) Brackett, Paschen and Pfund (4) All of these

Sol. Answer (3)

25. Three energy levels L_1, L_2 and L_3 of a hydrogen atom correspond to increasing values of energy *i.e.*, $E_{L_1} < E_{L_2} < E_{L_3}$. If the wavelength corresponding to the transitions L_3 to L_2, L_2 to L_1 and L_3 to L_1 are λ_3, λ_2 and λ_1 respectively then

(1) $\lambda_3 = \lambda_1 + \lambda_2$ (2) $\lambda_1 = \dfrac{\lambda_2\lambda_3}{\lambda_2 + \lambda_3}$ (3) $\lambda_1 = \lambda_2 + \lambda_3$ (4) $\lambda_3 = \dfrac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

Sol. Answer (2)

$$\frac{1}{\lambda_1} = \frac{E_{L_3} - E_{L_1}}{\lambda c}$$

$$\frac{1}{\lambda_2} = \frac{E_{L_2} - E_{L_1}}{\lambda c}$$

$$\frac{1}{\lambda_3} = \frac{E_{L_3} - E_{L_2}}{\lambda c}$$

$$\frac{1}{\lambda_2} + \frac{1}{\lambda_3} = \frac{1}{\lambda_1}$$

$$\therefore \quad \lambda_1 = \frac{\lambda_2\lambda_3}{\lambda_2 + \lambda_3}$$

26. If the wavelength of first member of Lyman series is λ then calculate the wavelength of first member of Pfund series

(1) $\dfrac{675}{11}\lambda$ (2) $\dfrac{245}{11}\lambda$ (3) $\dfrac{322}{13}\lambda$ (4) $\dfrac{289}{11}\lambda$

Sol. Answer (1)

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

For first line of Lyman series, $n_i = 2$, $n_f = 1$

For first line of Pfund series, $n_i = 6$, $n_f = 5$

$$\therefore \quad \frac{\lambda'}{\lambda} = \frac{\left(\frac{1}{1^2} - \frac{1}{2^2}\right)}{\left(\frac{1}{5^2} - \frac{1}{6^2}\right)}$$

$$\Rightarrow \quad \lambda' = \frac{675}{11}\lambda$$

27. In Bohr's model of the hydrogen atom, the ratio between the period of revolution of an electron in the orbit of $n = 1$ to the period of revolution of the electron in the orbit $n = 2$ is

(1) 2 : 1 (2) 1 : 2 (3) 1 : 4 (4) 1 : 8

Sol. Answer (4)

Time period $\propto n^3$

$$\therefore \quad \frac{T_1}{T_2} = \frac{1}{8}$$

28. How many times do the electron go round the second Bohr orbit in a second?

(1) 2.3×10^{12} (2) 3.2×10^{14} (3) 8.3×10^{14} (4) 6.2×10^{14}

Sol. Answer (3)

Time period of second Bohr orbit

$$T_2 = 2^3 T_0$$

$$= 8 \times 1.51 \times 10^{-16}\text{ s}$$

$$\therefore \quad n = \frac{1s}{T_2} = \left(\frac{1}{8 \times 1.51 \times 10^{-16}}\right)$$

$$\Rightarrow \quad n \simeq 8.3 \times 10^{14}$$

29. If an electron in hydrogen atom jumps from third orbit to second orbit, the frequency of the emitted radiation is given by (c is speed of light)

(1) $\frac{3Rc}{29}$ (2) $\frac{5Rc}{36}$ (3) $\frac{7Rc}{36}$ (4) $\frac{8Rc}{31}$

Sol. Answer (2)

$$f = \frac{c}{\lambda} = Rc\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5Rc}{36}$$

30. If radius of first orbit of hydrogen atom is 5.29×10^{-11} m, the radius of fourth orbit will be

(1) 8.46 Å (2) 10.23 Å (3) 9.22 Å (4) 9.48 Å

Sol. Answer (1)

$r = n^2 r_0$

$\therefore$ $r = 16 \times 5.29 \times 10^{-11}$ m

$= 8.46 \times 10^{-10}$ m

31. Bohr's atomic model is applicable for

(1) Hydrogen atom only
(2) Unielectron atomic system only
(3) All atoms
(4) All isotopes of hydrogen only

Sol. Answer (2)

32. Let F_1 be the frequency of second line of Lyman series and F_2 be the frequency of first line of Balmer series then frequency of first line of Lyman series is given by

(1) $F_1 - F_2$
(2) $F_1 + F_2$
(3) $F_2 - F_1$
(4) $\dfrac{F_1F_2}{F_1+F_2}$

Sol. Answer (1)

$$F_1 = Rc\left(\frac{1}{1^2}-\frac{1}{3^2}\right)$$

$$F_2 = Rc\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$F_3 = Rc\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

Clearly, $F = F_1 - F_2$

33. If the difference between $(n + 1)^{th}$ Bohr radius and n^{th} Bohr radius is equal to the $(n - 1)^{th}$ Bohr radius then find the value of n

(1) 4
(2) 3
(3) 2
(4) 1

Sol. Answer (1)

$r_n = n^2 r_0$

$r_{n+1} = (n + 1)^2 r_0$

$r_{n-1} = (n - 1)^2 r_0$

By the question,

$r_{n+1} - r_n = r_{n-1}$

$\Rightarrow$ $(n + 1)^2 - n^2 = (n - 1)^2$

$\therefore$ $n = 4$

34. The lines in Balmer series have their wavelengths lying between

(1) 1266 Å to 3647 Å
(2) 642 Å to 3000 Å
(3) 3647 Å to 6563 Å
(4) Zero to infinity

Sol. Answer (3)

For Balmer series

$$\frac{1}{\lambda_{min}} = R\left(\frac{1}{2^2} - 0\right) = \frac{109678}{4}\text{cm}^{-1}$$

$$\Rightarrow \lambda_{min} = 3.647 \times 10^{-7}\text{ m} = 3647\text{ Å}$$

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

$$\Rightarrow \lambda_{max} = 6564\text{ Å}$$

35. Identify the incorrect relationship

(1) Number of waves in an orbit, $n = \frac{2\pi r}{\lambda}$

(2) Number of revolutions of an electron per second in n^{th} orbit = $\frac{v_n}{2\pi r_n}$

(3) Wavelength of an electron = $\frac{h}{p}$

(4) Speed of a (de Broglie wavelength) particle accelerated by a potential difference V is $v = \frac{2eV}{m}$

Sol. Answer (4)

36. Magnetic moment of an electron in hydrogen atom due to revolution around nucleus is $\frac{hS}{2\pi}$. Here h is Planck's constant and S is specific charge of electron. Kinetic energy of this electron is

(1) 4.53 eV (2) 1.51 eV (3) 3.4 eV (4) 6.8 eV

Sol. Answer (3)

$$M = \frac{neh}{4\pi m} = \frac{nhs}{4\pi} = \frac{hs}{2\pi}$$

$$\Rightarrow n = 2$$

So, $\text{K.E.} = \frac{13.6}{n^2} = 3.4\text{ eV}$

37. If He^+ ion undergoes transition $n = 2 \rightarrow 1$ the ratio of final to initial magnetic field due to motion of electron at the nucleus will

(1) 32 : 1 (2) 1 : 32 (3) 16 : 1 (4) 1 : 16

Sol. Answer (1)

$$B = \frac{\mu_0 . I}{2\pi r} \qquad [\ I = e\ f\ ]$$

$$\Rightarrow B = \frac{\mu_0 ef}{2\pi r} \qquad [\text{since } f \propto \frac{z^2}{n^3},\ r \propto n^2]$$

$$\Rightarrow B \propto \frac{1}{n^5}$$

$$\Rightarrow \frac{B_1}{B_2} = \left(\frac{n_2}{n_1}\right)^5 = \left(\frac{1}{2}\right)^5 = \frac{1}{32}$$

$$\Rightarrow \frac{B_2}{B_1} = \frac{32}{1}$$

38. If longest wavelength of Balmer series of H atom is λ then shortest wavelength of Lyman series will be

(1) $\frac{5}{36}\lambda$ (2) $\frac{5}{9}\lambda$ (3) $\frac{36}{5}\lambda$ (4) $\frac{9}{5}\lambda$

Sol. Answer (1)

Wave number (For transition $n_2 \rightarrow n_1$)

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

Longest wavelength of balmer series will be emitted when e^- jump from $n = 3$ to $n = 2$

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36}$$

Shortest wavelength of Lyman series

$$\frac{1}{\lambda'} = R\left(1 - \frac{1}{\infty}\right) = R$$

$$\Rightarrow \lambda' = \frac{5}{36}\lambda$$

39. An electron in a hydrogen atom makes a transition such that its kinetic energy increases, then

(1) The electron may have excited form $n = 2$ to $n = 3$

(2) Potential energy of the electron increases

(3) Potential energy of the electron decreases

(4) Total energy of the electron increases

Sol. Answer (3)

Kinetic energy will increase if it comes from higher orbit to lower orbit.

$$\text{K.E.} = -\frac{\text{P.E}}{Z}$$

So the potential energy will decrease.

40. A hydrogen atom and a Li^{2+} ion are both in the second excited state. If L_H and L_{Li} are their respective electronic angular momenta, and E_H and E_{Li} are their respective energies, then

(1) $L_H > L_{Li}$ and $|E_H| > |E_{Li}|$ (2) $L_H = L_{Li}$ and $|E_H| < |E_{Li}|$

(3) $L_H = L_{Li}$ and $|E_H| > |E_{Li}|$ (4) $L_H < L_{Li}$ and $|E_H| < |E_{Li}|$

Sol. Answer (2)

In second excited state $n = 3$

$$L = \frac{nh}{2\pi} \quad \Rightarrow \quad L_H = L_{L_i}$$

$$E\mu = \frac{-13.6}{n^2}Z^2 \quad \Rightarrow |E_H| < |E_{L_i}|$$

41. Imagine an atom made up of a proton and a hypothetical particle having double the mass of the electron but same charge as the electron. Apply the Bohr's atom model and consider all possible transitions of the hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to

(1) $\frac{9}{5R}$ (2) $\frac{36}{5R}$ (3) $\frac{18}{5R}$ (4) $\frac{4}{R}$

Sol. Answer (3)

$$\frac{1}{\lambda}=R'\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)Z^2$$

$$R=\frac{MC^4}{8\varepsilon_0^2h^3C} \qquad \Rightarrow R'=2R$$

For longest e^- will jump from n = 3 to n = 2

$$\Rightarrow \frac{1}{\lambda}=2R\left(\frac{1}{4}-\frac{1}{9}\right)=2\times\frac{5R}{36}$$

$$\Rightarrow \lambda=\frac{18}{5R}$$

42. When ultraviolet radiation is incident on a surface, no photoelectrons are emitted. It is possible to cause emission by using

(1) Infrared light (2) Visible light (3) X-rays (4) Microwaves

Sol. Answer (3)

It will be possible to cause the photoelectric effect with photons of greater energy *i.e.* smaller wavelength.

$\lambda_{X\text{-ray}}<\lambda_{\text{ultraviolet}}$.

43. The magnetic field at the centre of hydrogen atom due to the motion of the electron in the first Bohr orbit is B. The magnetic field at the centre due to motion of the electron in 2nd orbit is

(1) $\frac{B}{4}$ (2) $\frac{B}{8}$ (3) $\frac{B}{32}$ (4) $\frac{B}{64}$

Sol. Answer (3)

$$B_1=\frac{\mu_0}{4\pi}\frac{ev}{r_1^2} \qquad v\propto\frac{Z}{n}$$

$$r=\frac{n^2}{Z}$$

So $B\propto\frac{1}{n^5}$

B in 2nd orbit $\frac{B}{2^5}=\frac{B}{32}$.

44. The energy of a photon of characteristic X-rays from a coolidge tube comes from

(1) The kinetic energy of the striking electron

(2) The kinetic energy of the free electrons of target

(3) The kinetic energy of the ions of the target

(4) On atomic transition in the target

Sol. Answer (4)

The energy of a photon of characteristic X-rays from Coolidge tube is emitted after atomic transition in target. It does not depend on energy and intensity of incident photons. It depends on nature of target only.

45. A hydrogen atom in ground state absorbs 12.09 eV of energy. The orbital angular momentum of the electron

(1) Is doubles (2) Is halved

(3) Remains same (4) Becomes three times

Sol. Answer (4)

$E_1 = -13.6$

$E' = -13.6 + 12.09 = -1.51$ eV

So final value of principal quantum number = 3

$L_i = \frac{h}{2\pi}$

$L_f = 3\frac{h}{2\pi} = 3L_i.$

46. An excited hydrogen atom emits a photon of wavelength λ in returning to the ground state. The quantum number n of the excited state is given by (R = Rydberg constant)

(1) $\sqrt{\lambda R(\lambda R-1)}$ (2) $\sqrt{\frac{\lambda R}{(\lambda R-1)}}$ (3) $\sqrt{\frac{(\lambda R-1)}{\lambda R}}$ (4) $\sqrt{\frac{1}{\lambda R(\lambda R-1)}}$

Sol. Answer (2)

$$\frac{hc}{\lambda} = Rhc\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$

Here, $n_1 = 1$ and $n_2 = n$, so

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

$$\Rightarrow \frac{1}{R\lambda} = 1-\frac{1}{n^2}$$

$$\Rightarrow \frac{1}{n^2} = 1-\frac{1}{R\lambda}$$

$$\Rightarrow n = \sqrt{\frac{R\lambda}{\lambda R-1}}.$$

47. An electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$ where n_1 and n_2 are principal quantum numbers of the states. Assume the Bohr's model to be valid, the frequency of revolution in initial state is eight times that of final state. The ratio $\frac{n_1}{n_2}$ is

(1) 8 : 1 (2) 4 : 1 (3) 2 : 1 (4) 1 : 2

Sol. Answer (4)

Frequency of revolution $\propto \frac{1}{n^3}$

$$\frac{f_1}{f_2} = \left(\frac{n_2}{n_1}\right)^3 \qquad [f_1 = 8f_2]$$

$$\Rightarrow \frac{8}{1} = \left(\frac{n_2}{n_1}\right)^3$$

$$\Rightarrow \frac{n_2}{n_1} = \frac{2}{1}.$$

48. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is

(1) 802 nm (2) 823 nm (3) 1882 nm (4) 1648 nm

Sol. Answer (2)

Largest wavelength in ultraviolet region is for Lyman Series given by $\frac{4}{3R} = 122\,\text{nm}$.

Smallest wavelength in infrared region is for Paschen Series given by $\frac{9}{R} = \frac{122 \times 27}{4} \approx 823\,\text{nm}$.

49. Electrons with de Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength of the emitted X-rays is

(1) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (2) $\lambda_0 = \frac{2h}{mc}$ (3) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (4) $\lambda_0 = \lambda$

Sol. Answer (1)

For X-ray photon $E = \frac{hc}{\lambda_0}$

$$\lambda_0 = \frac{hc}{E} \quad \text{...(i)}$$

for electron $\lambda = \frac{h}{\sqrt{2mE}}$ ...(ii)

From equation (i) and (ii)

$$\lambda_0 = \frac{2mc\lambda^2}{h}$$

50. Which one of the following statements is **WRONG** in the context of X - rays generated from a X-ray tube?

(1) Wavelength of characteristic X-rays decreases when the atomic number of the target increases

(2) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target

(3) Intensity of the characteristic X-rays depends on the electrical power given to the X-ray tube

(4) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

Sol. Answer (2)

Cut off wavelength $\lambda_c = \frac{hc}{eV}$, where V is the accelerating voltage.

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