19 ATOMS, MOLECULES & NUCLEI

Learning Objectives

- Bohr's model of atom
- Hydrogen spectrum
- Maser and Laser as Light sources
- de Broglie hypothesis
- Wavelength of an electron
- Davisson & Germer experiment
- Elementary idea of electron microscope

Q.1. State and explain postulate of Bohr's atomic model ?

Ans :

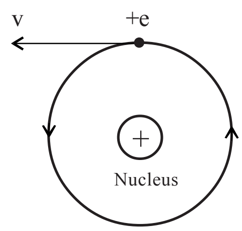
Neils Bohr in 1913 modified Rutherford's atom model in order to explain the stability of the atom and the emission of sharp spectral lines. He proposed the following postulates

1) **First Postulate :**

i) An electron in an atom revolves around the nucleus in a circular orbit.

ii) The centripetal force required for circular motion of the electron is provided by the electrostatic force of attraction between the electron and the nucleus.

Explanation : Consider an electron revolving around a hydrogen nucleus.



Let, m = mass of the electron

– e = charge on the electron,

r = radius of the orbit

v = linear speed of the electron.

+ e = charge on the hydrogen nucleus.

iii) According to Bohr's first postulate, centripetal force required for uniform circular motion of the electron is equal to the electrostatic force of attraction between the electron and the nucleus.

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

∴ Centripetal force = Force of attraction between electron and the nucleus

$$\boxed{\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_o} \cdot \frac{e^2}{r^2}} \qquad .... 1$$

2) **Second Postulate :** The electrons can revolve round the nucleus only in those permissible orbits for which the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$ (Where, h is Planck's constant)

F **Explanation :** According to Bohr's Second Postulates

$$\boxed{} \qquad .... 2$$

∴ n = 1,2,3.......

Where n is called princsipal quantum number.

F An electron revolving in these orbits does not radiate any energy, are called stationary orbits.

3) **Third Postulate :** An atom radiates energy, only when an electron jumps from a stationary orbit of higher energy to an orbit of lower energy.

- **Explanation :** If the electron jumps from an orbit of energy E_n to an orbit of energy E_p, a photon of energy is emitted.

According to Bohr's third postulate

$$\boxed{h\nu = E_n - E_p} \qquad \text{.................. } 3$$

This condition is called Bohr frequency condition.

Q.2. Obtain an expression for radius of electron in n^{th} Bohr's orbit.

Ans :

i) Consider the electron revolving in the n^{th} orbit around a hydrogen nucleus.

Let, m = mass of the electron

– e = charge on the electron

r = radius of the orbit

v = linear speed of the electron.

e = charge on the nucleus.

ii) From Bohr's 1^{st} Postulate,

$$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_o r^2} \qquad \text{..............} 1$$

$$\therefore v^2 = \frac{e^2}{4\pi\varepsilon_o m r}$$

iii) According to Bohr's second postulate,

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

Squaring both side

$$\therefore \qquad \text{............ } 2$$

iv) From equations (1) and (2)

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

$$\text{.............}3$$

This expression gives the radius of the orbit of the electron.

But $r = \dfrac{h^2 \epsilon_0}{\pi m e^2}$ = constant = 0.53 x 10^{-10} m

$\therefore r \propto n^2$

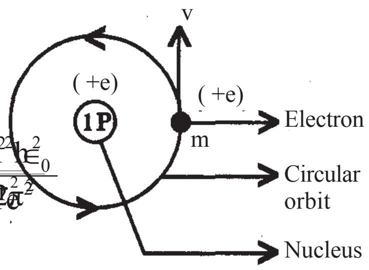
It is seen that the radius of the orbit is proportional to the square of the principal quantum number.

Q.3. Show that the total energy of electron in n^{th} Bohr's orbit is inversely proportional to the square of principle quantum number.

Ans : Energy of an electron :

The total energy of the electron is the sum of its potential energy and kinetic energy in its orbit.

Consider an electron (–e) is revolving in circular orbit around the nucleus (+ e).



- **Potential energy of electron :**

Electric potential at a distance 'r' from the hydrogen nucleus is equal to $= \dfrac{1}{8\pi\epsilon_0}\dfrac{e^2}{r} - \dfrac{1}{4\pi\epsilon_0}\dfrac{e^2}{r}$

$\therefore$ Potential energy = Charge on electron x electric potential

Ep = ... 4

- **Kinetic energy of electron :**

The kinetic energy of the electron in the n^{th} orbit is,

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

But,

$E_K =$ 5

Hence, the total energy of an electron in its n^{th} orbit is $E_n = E_K + E_P$

$$= \frac{1}{8\pi \in_0} \frac{e^2}{r} - \frac{1}{4\pi \in_0} \frac{e^2}{r}$$

$E_n =$ 6

But $r = \dfrac{\in_0 n^2 h^2}{\pi m e^2}$

Substituting the value of r in equation (6) we get.

$E_n =$

$E_n =$ 7

This expression gives the energy of the electron in the n^{th} orbit.

Note :

i) From equation (7) the negative sign indicates that, the electron is bound to the nucleus due to electrostatic force.

But, $\dfrac{m e^4}{8 \in_0 h^2} = 13.6 \text{ eV} = \text{constant}$

$\therefore$ 8

ii) As there is a negative sign in equation (8), it is seen that the energy of the electron in its orbits increases as n increases.

$\therefore \quad \propto$ 9

Hence, the energy of the electron in the n^{th} orbit is inversely proportional to the square of the principal quantum number.

Q.4. Explain the origin of spectral lines on the basis of Bohr's theory. Derive an expression for wavelength of spectral lines. In hydrogen atom.

Ans : Origin of spectral line :

1. The hydrogen atom has only one electron and has an energy of – 13.6 eV. When the electron is in this level, the atom is said to be in the ground state.
2. If hydrogen gas is heated, it receives energy. If the energy absorbed is equal to or greater than 13.6 eV the electron escapes from the atom.
3. If hydrogen gas absorbed energy is less than 13.6 eV, the electron jumps from lower energy orbit to higher energy orbit. The atom is said to be in an excited state.
4. In the excited state, the atom is unstable. After a short interval, the electrons jump into the lowest energy state of the atom.
5. Whenever an electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference in energies of the two levels is emitted as a radiation of particular wavelength. It is called spectral line.

6) Let E_n and E_p are the energy of the electron in the n^{th} orbit and p^{th} orbit respectively.

According to Bohr's third postulate.

$E_n - E_p = h\nu$ 1

But $E_n =$ and $E_p =$

$\therefore \; h\nu =$

$h\nu =$

$$\nu = \frac{m e^4}{8 \in_0^2 h^3}\left[\frac{1}{p^2} - \frac{1}{n^2}\right]$$

But, $\nu = \dfrac{C}{\lambda}$

Where,

= Wave number

λ = The wavelength of the radiation emitted

$$\therefore \frac{1}{\lambda} = \frac{me^4}{8 \in_0^2 h^3 C}\left[\frac{1}{p^2} - \frac{1}{n^2}\right] \quad .... 2$$

$$\therefore \bar{\lambda} = \frac{1}{\lambda} = R\left[\frac{1}{p^2} - \frac{1}{n^2}\right] \quad ....3$$

Where $\therefore R = \frac{me^4}{8 \in_0^2 h^3 C} = 1.094 \times 10^7 m^{-1}$

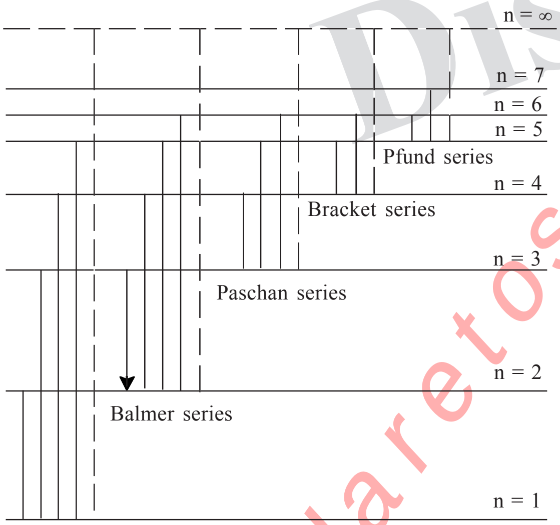
called Rydberg's constant.

This expression gives the origin of spectral lines of H - atoms.

Q.5. Explain the different series in hydrogen spectrum.

Ans : Lyman Series :

When the electron jumps from any of the outer orbits to the first orbit, the spectral lines emitted are in the ultraviolet region of the spectrum and they are said to form a series called Lyman series.



Here, p = 1 n = 2, 3, 4, ...

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{(1)^2} - \frac{1}{n^2}\right] \quad .... 4$$

This series lies in ultraviolet region.

2. **Balmer Series :** When the electron jumps from any of the outer orbits to the second orbit, we get a spectral series called the Balmer series.

Here, p = 2, n = 3, 4, 5, ...

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{(2)^2} - \frac{1}{n^2}\right] \quad .... 5$$

This series lies in the visible region.

3. **Paschen Series :** When the electron jumps any of the outer orbits to the third orbit, we get a spectral series called the Paschen series.

Here p = 3, n = 4, 5, 6, ...

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{(3)^2} - \frac{1}{n^2}\right] \quad .... 6$$

This series is in the infrared region.

4. **Brackett Series :** When the electron jumps any of the outer orbits to the fourth orbit, we get a spectral series called the Brackett series.

Here, p = 4, n = 5, 6, 7, ...

$$\therefore \frac{1}{\lambda} = R\left[\frac{1}{(4)^2} - \frac{1}{n^2}\right] \quad ....7$$

This series is in the infrared region.

5. **P fund Series :** When the electron jumps any of the outer orbits to the fifth orbit, we get a spectral series called the Pfund series.

Here, p = 5, n = 6, 7, 8, ...

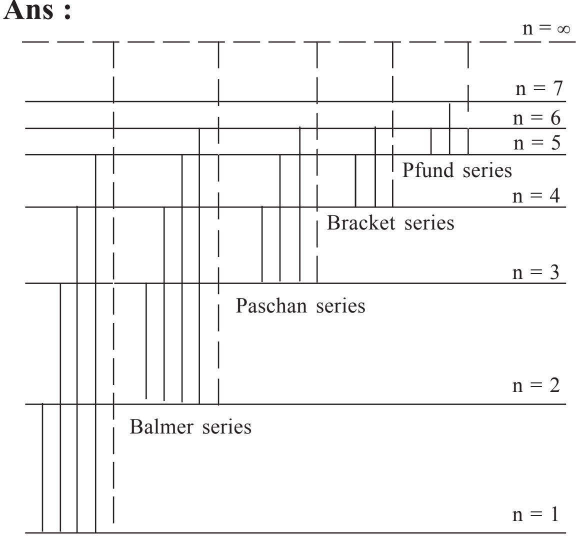
........8

This series is in the infrared region.

- Horizontal lines are drawn which represent energy levels of H-atom.
- Vertical lines are drawn which represent the transition of electrons.

Q.6. Draw neat lebelled energy level diagram for hydrogen atom.

Ans :

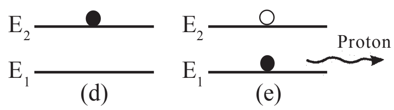


Q.7. Explain the following terms.

Ans :• Spontaneous Emission :

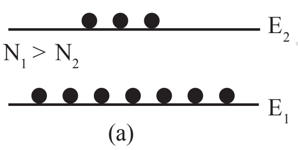
a) An atom may undergo transition between two energy states E_1 and E_2, if it emits or absorbs a photon of the energy, $E_2 - E_1 = h\nu$.

e) If the excited energy level is an ordinary level, the excited atoms return to the ground energy level. During this transition, a photon of energy $h\nu$; is emitted. This is called spontaneous emission, shown in fig.



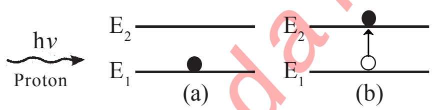
b) Normal population :

In a system of thermal equilibrium, the number of atoms in the ground state is greater than the number of atoms in the excited state.This is called normal population shown in fig.



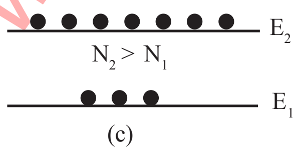
3) Stimulated absorption :

If photons of energy $h\nu$ are incident on the sample. The photon can interact with the atoms in the ground state and are taken to excited state. This is called stimulated or induced absorption . As shown in fig.



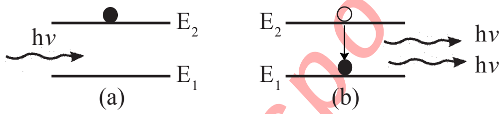
4) Population inversion :

If the atoms in the ground state are pumped to the excited state, the number of atoms in the excited state becomes greater than the number of atoms in the ground state. This is called population inversion shown in fig.



5) Stimulated emission :

If the excited state is a metastable state, a photon of energy $h\nu$ can stimulate the atom to move to its ground state, during which process the atom emits an additional photon, whose energy is also $h\nu$. This process is called stimulated emission.



Q.8. What is laser. Write its characteristics.

Ans : Laser :

A process by which highly monochromatic, coherent and perfectly parallel beam of light can be obtain is called laser.

i) The laser is a light source that produces a beam of highly coherent and monochromatic light as a result of cooperative emission from many atoms.

ii) The name 'Laser' is an acronym for Light amplification by stimulated emission of radiation.

• **Characteristics of Laser :**

1. The laser beam is monochromatic.
2. The laser beam is coherent.
3. The laser beam does not diverge at all.
4. The laser beam is extremely intense.

Q.9. Explain the principle of formation of laser.

Ans : Laser can be produce by using an atomic system having metastable state.

ii) Let a three level system i.e. E_1 for ground state, E_2 for metastable state and E_3 is energy for excited state.

iii) It is made that number of atoms in E_2 is greater than number of atoms in E_1.

iv) When photon of energy $h\nu = E_2 - E_1$ is incident on metastable atom, its stimulate the atom to return to ground state.

v) During this two photons are emitted having same phase and same direction of incident photon.

vi) These emitted photons are again made to incident on two metastable atoms giving rise to four photons. and this process continues.

vii) This process is called amplification of light and laser is produced.

Q.9. Write the application of LASER.

Ans : Applications of LASER :

- Industrial applications (uses)

1. To drill fine holes in diamonds, hard sheet etc.
2. To cutting thick sheets of hard metals.
3. To test the quantity of the materials.

   To vapourize the unwanted materials during the manufacture of semiconductor chips.

- **Medical Applications,**

1. The laser are used in endoscopy.
2. For the treatment of human cancer.
3. **For the microsurgery. Scientific Application:**

1. For modulated to transmit large number of messages at a time in radio, television and telephone.
2. For optical fiber communication.
3. In Raman spectroscopy.
4. In holography.
5. The earth-moon distance has been measured.

Q.10.What is MASER. Write its application

The term MASER stands for Microwave Amplification by stimulated Emission of Radiation. The working of maser is similar to that of laser.

Application of MASER :

MASERS have few applications due to their low band width, low power and operating temperature. They are as follows:

1. Masers provides very sharp, constant oscillating signal and used as high precision frequency atomic clock.
2. It is a source of ideal single frequency thus they can be transmitted over very long distances with very little loss.
3. They are used as amplifier in satellite communication and radio telescope.
4. They are used to destroy the control system of planes.
5. They often used as weapons in scierfee fiction movies.
6. Maser weapons can be used to bombard humans to cause the disfunctionality of the brain.

Q.11.Distinguish between LASER and MASER

LASER	MASER
1. LASER stands for light amplification by stimulated emission of radiation.	1.MASER stands for microwave amplification by stimulated emission of radiation.
2. Laser produces and amplifies elecro-magnetic radiations in ultraviolet or visible region of spectrum.	2. Maser produces and electromagnetic amplifies radiations in microwave region of spectrum.
3. Lasers have short wavelength than Masers.	3. Masers have long wavelength than Lasers.
4. Lasers have high power than Masers.	4. Masers have low power than Lasers.
5. Laser can be operated at normal temperature operated at normal hence it has much more applications than Maser.	5. Masers can not be temperature and have smaller band width hence it has less application than Laser.

Q.12.What is de Broglie Hypothesis.

Ans : In 1924, a French Physicist Louis de Broglie put forward the hypothesis that moving particles should possess wave like properties under suitable conditions.

Q.13.Obtain and expression for de Broglie wavelength.

i) If a particle acts like a wave, it should have a wavelength and a frequency, de Broglie equated the energy equations of Planck (wave) and Einstein (particles).

ii) For a wave of frequency v, the energy associated with each photon is given by Plank's relation,

$$E = hv \qquad \text{............ 1}$$

Where 'h' is Planck's constant.

iii) According to Einstein's mass energy relation a mass m is equivalent to energy.

$E = mc^2$ 3

Where c is the velocity of light

If $h\nu = mc^2$

$\therefore \frac{hc}{\lambda} = mc^2$

.... 3

For a particle moving with a velocity v, if v = c.

From equation (3)

$\therefore$

where p = mv = the momentum of the particle.

Q.14.Derive an expression of wavelength of electron accelerated through potential difference of V.

Ans :

i) Consider an electron of mass m and charge e is accelerated through a potential difference v_1 then the energy ev is equal to kinetic energy of the electron.

.... 1

ii) The de Broglie wavelength is

.... 2

iii) Substituting the value of v,

.... 3

iv) Substituting the value in equation (3)

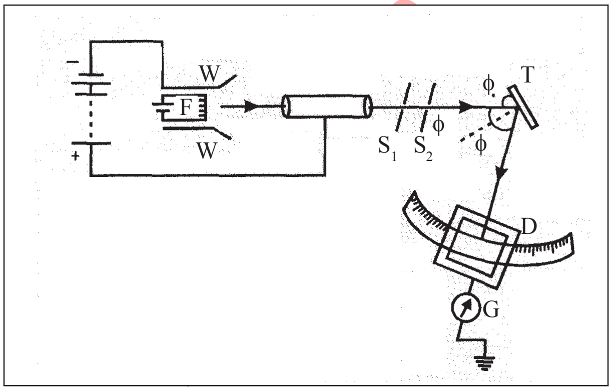
.... 4

This expression gives wavelength of an electron.

Q.15.Describe Davisson and Germer Experiment for the wave nature of electron.

Ans :

i) The first experimental evidence of matter waves was given by two American Physicists Davisson and Germer in 1927.



ii) They also measured the de Broglie wavelength associated with an electron.

iii) The experimental set up is shown in the fig. A beam of electrons emitted from a heated filament F is accelerated through a potential difference V applied between cylinders WW and .

iv) After passing through the slits S_1 and S_2, the beam strikes the nickel metal target (T).

v) The scattered electron beam is detected by Faraday cylinder D for various angles (Φ) Faraday cylinder moves on a graduated circular scale and is connected to a galvanometer (G).

vi) The current is a measure of the intensity of the diffracted beam of electrons.

vii) The whole apparatus was completely enclosed in highly evacuated chamber.

viii) The intensity of diffracted beam of electrons is maximum at 54 volts for an angle of scattering

.

ix) The interplaner distance of nickel crystal is found to be 0.909 A°.

x) Using Bragg's Law,

$2d \sin\theta = n\lambda$

Putting n = 1 and the glancing angle 50°

$\therefore \lambda = 2d \sin\theta = 2.15 \sin 50° = 1.66 A^0$

xi) According to de Broglie's wavelength for a beam at 54 v is given by,

$\lambda = 1.66\ A^0$

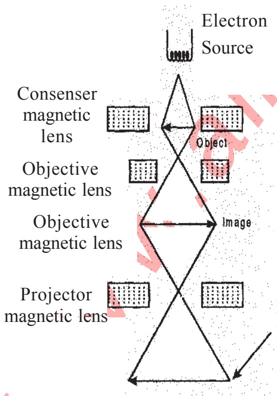
The excellent agreement between the two results for the wavelengths confirms the de Broglie's postulate for the matter waves.

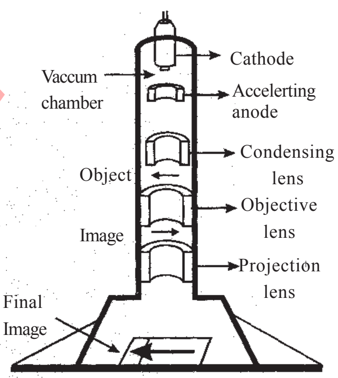
Q.16. Describe electron microscope with block diagram

Ans : Electron Microscope

Principle : Electron microscope based on the following principles are,

1) Particles such as electrons have a wave nature, similar to light rays but of much shorter wavelength.
2) Electrons can be focussed by suitable electric and magnetic fields, very much like light rays are focussed by a glass lenses.
3) An electron microscope is usually of transmission type in which magnetic lenses of short focal length are used to obtain large magnification.
4) An electron beam emitted by a filament is accelerated through a large potential difference in a device called electron gun.





5) The fine beam of electrons is made to pass through the centre of the condenser magnetic lens.
6) The electrons get deflected to form a parallel beam which strikes the object to be magnified.
7) The objective magnetic lens causes the electron beam to diverge to produce enlarged image of the object.
8) The electromagnetic C (Projector magnetic lens) focusses the electron beam from the part of the enlarged image on the fluorescent screen producing still greater magnification.
9) It can be obtained on a suitable photographic plate for a permanent record.
10) The apparatus is mounted in a chamber which is completely evacuated.

Uses :

1. It is used in the industry, to study the structure of fibres, surface of metals.
2. It is used to study virus and bacteria.
3. It has been used to study of atomic structure.

IMPORTANT FORMULAE

1. **Centripetal force of an electron.**

2. **Angular momentum of electron.**

$$m\,v\,r = \frac{nh}{2\pi}$$

3. **Energy of Photon.**

$hV = E_n - E_P$

4. **Radius of electron.**

5. **Enegry of electron in n^{th} orbit**

$$E = \frac{me^2}{8 \in_0^2 h^2 n^2}$$

6. **Wavelength of spectral line.**

$$\frac{1}{\lambda} = R\left[\frac{1}{p^2} - \frac{1}{n^2}\right] \qquad n = 2,3,4............$$

7. Moment of Photon.

$$P = \frac{h\nu}{C}$$

8. The de Broglie wavelength of electron.

9. Bragg's law.

SOLVED EXAMPLES

1. Prove that the angular speed of electron in Bohr orbit is inversely proportional to the cube of principal quantum number.

Solution : Consider an electron of mass ma and charge - e is revolving in a Bohr orbit of radius r. Let be the Linear speed and ωbe the angular speed of electron.

According to Bohr's second postulate.

$$I\omega = \frac{nh}{2\omega}$$

$$\therefore \quad \omega = \frac{nh}{2\omega I}$$

$$\therefore \quad \omega = \frac{nh}{2\pi mr^2}$$

But $\quad r = \frac{\in_0 n^2h^2}{\pi me^2} \quad \therefore r^2 = \frac{\in_0^2 n^2h^4}{\pi^2 m^2 e^4}$

$$\therefore \quad \omega = \frac{\pi^2 m^2 e^4}{\in_0^2 n^4 e^4}$$

$$\omega = \frac{\pi^2 m^2 e^4}{\in_0^2 n^4 e^4}$$

As π m,e, $\in_0$ and h are constants.

$$\therefore \quad \omega \propto \frac{1}{n^3}$$

2. Find the angular momentum of electron in 4^{th} orbit of hydrogen atom.

Solution :

Given data : n = 4, L = ?

Angular momentum of electron in n^{th} orbit.

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

$$L = \frac{4 \times 6.63 \times 10^{-34}}{2 \times 3.14}$$

$$\mathbf{L = 4.22 \times 10^{-34}\ kg\ m^2/s}$$

3. Calculate the speed of electron in 3^{rd} orbit of hydrogen atom.

Solution :

Given data : V = ? n = 3

The seed of electron in n^{th} orbit.

$$v = \frac{e^2}{2 \in_0 nh}$$

$$v = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 3 \times 6.63 \times 10^{-34}}$$

$$v = \frac{2.56 \times 10^{-36}}{17.7 \times 19.89 \times 10^{-46}}$$

$$v = \frac{2.56}{353.05} \times 10^8$$

$$\mathbf{v = 7.3 \times 10^5 m/s}$$

4. Find the radius of first orbit of an electron in hydrogen atom. Hence find the radius of 3rd orbit of hydrogen atom.

Solution :

Given data : r_1 = ? n = 1, r_3 = ? n = 3

The radius of n^{th} Bohr orbit.

$$r = \frac{\in_0 n^2h^2}{\pi me^2}$$

For first orbit n = 1

$$\therefore \quad r_1 = \frac{8.85 \times 10^{-12} \times (6.63 \times 10^{-34})^2}{3.14 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$$r_1 = \frac{8.85 \times 6.63 \times 6.63}{3.14 \times 9.1 \times 1.6 \times 1.6} \times 10^{-11}$$

$$\mathbf{r_1 = 0.5138\ A.\ U.}$$

Now $\quad r_3 = (3)^2 \times r_1$

$r_3 = 9 \times 0.5138$

$$\mathbf{r_3 = 4.7862\ A.\ U.}$$

5. Find the frequency of radiation emitted when an electron in hydrogen atom jumps from fourth obit to second orbit (Given : E_1 = 13.6 eV)

Solution :

Given data : $E_1 = -13.6$ eV, $v = ?$

The energy of electron in n^{th} orbit

$$E_n = \frac{-me^4}{8\epsilon_0^2 n^2h^2}$$

$$\therefore \quad E_1 = \frac{-me^4}{8\epsilon_0^2 h^2}$$

$$\therefore \quad E_n = \frac{E_1}{n^2}$$

For fourth orbit $n = 2$

$$\therefore \quad E_2 = \frac{-13.6}{(4)^2}$$

$$E_2 = -3.4 \text{ eV}$$

For fourth orbit $n = 4$

$$\therefore \quad E_4 = \frac{-13.6}{(4)^2}$$

$$E_4 = -0.85 \text{ eV}$$

Now $h\nu = E_n - E_p$

$$\therefore \quad v = \frac{E_4 - E_2}{h}$$

$$v = \frac{-0.85 + 3.4}{6.63\times10^{-34}}\frac{\text{eV}}{\text{Js}}$$

$$v = \frac{2.55}{6.63\times10^{-34}}\frac{\text{eV}}{\text{Js}}$$

$$v = \frac{2.55\times1.6\times10^{-19}}{6.63\times10^{-34}}\frac{\text{J}}{\text{Js}}$$

$$\mathbf{v = 6.154\times10^{14}\ Hz}$$

6. **The energy of electron in ground state of hydrogen atom is – 13.6 eV. Find the K.E and P.E of electron in same state.**

Solution :

Given data : $E = -13.6$eV, $n = 1$, K.E. = ?, P.E=?

The K.E, P. E. And T.E. of electron in n^{th} orbit.

$$\text{P.E.} = \frac{-me^4}{4\epsilon_0^2 n^2h^2}$$

$$\text{K.E.} = \frac{-me^4}{8\epsilon_0^2 n^2h^2}$$

$$\text{T.E.} = \frac{-me^4}{8\epsilon_0^2 n^2h^2}$$

Comparing above equations.

K. E. = – T.E.

K. E. = – (–13.6)

K. E. = 13.6 eV

Similarly :

P. E. = 2 × T.E.

P. E. = 2 × (–13.6)

P. E. = – 27. eV

7. **Calculate the limiting wavelengths of layman series in hydrogen spectrum. (Given : R = 1.097 × 10^7)**

Solution : The wavelength of spectral line.

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

For maximum (largest) wavelength P = 1 and n = 2

$$\therefore \quad \frac{1}{\lambda_1} = 1.09\times10^7\left(\frac{1}{(1)^2} - \frac{1}{(2)^2}\right)$$

$$\therefore \quad \frac{1}{\lambda_1} = 1.097\times10^7\left(\frac{1}{1} - \frac{1}{4}\right)$$

$$\frac{1}{\lambda_1} = 1.097\times10^7\left(\frac{3}{4}\right)$$

$$\boldsymbol{\lambda_1 = 1.215\times10^{-7}\,\mathrm{m}}$$

For minimum (shortest) wavelength p = 1 and n = ∞

$$\therefore \quad \frac{1}{\lambda_2} = R\left(\frac{1}{(1)^2} - \frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_2} = R(1-0)$$

$$\therefore \quad \lambda_2 = \frac{1}{R}$$

$$\lambda_2 = \frac{1}{0.9115\times10^{-7}}$$

$$\boldsymbol{\lambda_2 = 0.9115\times10^{-7}\,\mathrm{m}}$$

8. **The energy of electron in ground state of hydrogen atom is – 13.6 eV Find Rydberg's constant.**

Solution :

Given data : E_1– 13.6 eV = –13.6 × 10^{-19}J, R = ?

Energy of electron in n^{th} orbit.

$$E_n = \frac{-me^4}{8\epsilon_0^2 n^2 h^2}$$

For first orbit n = 1

$$E_1 = \frac{-me^4}{8\epsilon_0^2 h^2}$$

Rydberg's constant is given by.

$$R = \frac{me^4}{8\epsilon_0^2 ch^3}$$

$$R = \frac{-E_1}{hc}$$

$$R = \frac{13.6\times1.6\times10^{-19}}{6.63\times10^{-34}\times3\times10^8}$$

$$R = \frac{21.76}{19.89}\times10^7$$

$$\mathbf{R = 1.094 \times 10^7 \text{ Per meter}}$$

9. The wavelength of H line of Blamer series is 6561A. U. Find the shortest wavelength of paschen series.

Solution :

Given data : $\lambda^1 = 6561$ A. U. $\lambda_2 = ?$

The wavelength of spectral lines.

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

For H_∞ line of Balmer series P = 2 and n = 3

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

$$\frac{1}{\lambda_1} = R\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\frac{1}{\lambda_1} = R\left(\frac{9-4}{36}\right)$$

$$\therefore \quad \lambda_1 = \frac{36}{5R} \qquad \text{......(1)}$$

For shortest wavelength of paschen series P = and n = ∞

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

$$\frac{1}{\lambda_2} = R\left(\frac{1}{9} - 0\right)$$

$$\therefore \quad \lambda_2 = \frac{9}{R} \qquad \text{.......2}$$

From equations (1) and (2).

$$\frac{\lambda_2}{\lambda_1} = \frac{9}{R}\times\frac{5R}{36}$$

$$\lambda_2 = \frac{45\times\lambda_1}{36}$$

$$\mathbf{\lambda_2 = 8201.25 \text{ A. U.}}$$

10. Calculate the wave number of shortest wavelengths line of Balmer series Given R = 1.097 × 10⁷ Per meter.)

Solution :

Given data : $\bar{v} = ?$, p = 2, n = ∞,

R = 1.097×10^7 per metre.

The wavelength of spectral lines.

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

For shortest wavelenght of Balmer series P = 2 and n = ∞

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

$$\therefore \quad \bar{v} = R\left(\frac{1}{4} - 0\right)$$

$$\bar{v} = 1.097\times10^7\times\frac{1}{4}$$

$$\mathbf{\bar{v} = 2.7425 \times 10^6 \text{ Per metre.}}$$

11. Find the Broglie wavelength of electron when it is accelerated through a potential difference of 100 volt.

Solution :

Given data : $\lambda = ?$, V = 100 volt

de Broglie wavelength of electron.

$$\lambda = \frac{12.27\times10^{-10}}{\sqrt{V}}$$

$$\lambda = \frac{12.27\times10^{-10}}{\sqrt{100}}$$

$$\lambda = 1.227 \times 10^{-10} \text{ m}$$

$$\mathbf{\lambda = 1.227 \text{ A. U.}}$$

PROBLEMS FOR PRACTICE

1. The radius of the second orbit of the electron in a Hydrogen atom is 2.127×10^{-10} m. Find the centripetal force acting on the electron in the second orbit. **[Ans :** $(C.P.F.)_2 = 5.09 \times 10^{-9}$ N]
2. The radius of the first orbit of the electron in a Hydrogen atom is 5.318×10^{-11} m. Find the centripetal force acting on the electron in the second orbit.**[Ans :** $(C.P.F.)_2 = 5.093 \times 10^{-9}$ N]
3. Find the angular momentum of the electron in the third orbit in a Hydrogen atom. (h is given) [**Ans :** $L_3 = 3.167 \times 10^{-34}$ kgm^2 /s]
4. Find the change in the angular momentum of the electron when it jumps from fourth orbit to the first orbit in a Hydrogen atom. (h is given) [Ans : $L_4 - L_1 = 3.167 \times 10^{-34}$ kgm^2 /s]
5. Calculate the radius of the second Bohr orbit of the electron in the Hydrogen atom. (Given : ε_o , h , m & e) . **[Ans : $r_2 = 2.127$ A^0]**
6. Find the radius of the second Bohr orbit in Hydrogen atom. Henece find the radius of the third orbit. [**Ans. :** $r_2 = 2.127$ A^0 $r_3 = 4.786$ A^0]
7. If the radius of first Bohr orbit of H - atom is 0.53 A^0 Calculate the radius of the 10th orbit. [**Ans.** : $r_{10} = 53$ A^0]
8. If the radius of first Bohr orbit of H - atom is 0.53 A^0 Calculate the radius of the Fourth orbit. [**Ans.** : $r_4 = 8.48$ A^0]
9. If the radius of third Bohr orbit in Hydrogen atom is 47.7×10^{-11} m. What will be the radius of the first orbit. [**Ans.** : $r_1 = 5.3 \times 10^{-11}$ m]
10. Find the speed of the electron in the second orbit in a hydrogen atom. (h , ε_o ,e and are given) [**Ans. :** $v_2 = 1.091 \times 10^6$ m/s]
11. Calculate the linear speed of the electron in the first Bohr orbit of a hydrogen atom. (Given : h, m and $r_1 = 0.53 \times 10^{-10}$ m) [**Ans. :** $v_1 = 2.189 \times 10^6$ m/s]
12. The speed of the electron in the first orbit is 2.182×10^6 m/s Find the speed of the electron in the third orbit. [**Ans :** $v_3 = 7.273 \times 10^5$ m/s]
13. Linear speed of the electron in the fourth Bohr orbit is 5.45×10^5 m/s. Calculate its linear speed in tenth orbit of the hydrogen atom. [**Ans :** $v_{10} = 2.18 \times 10^5$ m/s]

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