CHAPTER 12

ATOMS

ONE MARK QUESTIONS WITH ANSWER

1. **Who discovered electrons?**

Ans: Electrons were discovered by J.J Thomason in the year 1897.

2. **What is the electric charge on an atom?**

Ans: At atom of an element is electrically neutral.

3. **Who proposed the first model of an atom?**

Ans: J.J. Thomson proposed the first model of an atom in the year 1898.

4. **Name the sources which emit electromagnetic radiations forming a continuous emission spectrum.**

Ans: Condensed matter like solids and liquids and non-condensed matter lie dense gases at all temperatures emit electromagnetic radiations of several wavelengths as a continuous spectrum.

5. **How does the spectrum emitted by rarefied gases different from those dense gases?**

Ans: In the rarefied gases ,the separation between atoms or molecules are farther apart. Hence the atoms give discrete wavelengths without any interaction with the neighbouring atoms.

6. **Give any one difference between Thomson's model and Rutherford's model of an atom.**

Ans: In the Thomson's atom model, electrons are in stable equilibrium while in the Rutherford's atom model electrons always experience a net force $\frac{mv^2}{r}$ due to electrostatic force of attraction between electron and nucleus.

7. **In which model atoms become unstable?**

Ans: In Rutherford atom model. (An accelerating electron radiates energy and spiral around the nucleus. Ultimately electrons should fall inside the nucleus.)

8. What is a stationary orbit?

Ans: A stationary orbit is one in which the revolving electron does not radiate energy.

9. Give the relation between radius and principle Quantum number of an atom.

Ans: $r_n \propto n^2$.

10. Are the electron orbits equally spaced?

Ans: No. Electron orbits are unequally spaced.

11. What is the relation between the energy of an electron and the principle Quantum,number?

Ans: $E_n \propto \frac{1}{n^2}$

12. What is excited state of an atom?

Ans: When atom is given sufficient energy, the transition takes place to an orbit of higher energy. The atom is then said to be in an excited state.

13. What is wave number of spectral line?

Ans: Wave number represents number of waves present in one metre length of the medium.

14. What is the value of Rydberg's constant?

Ans: R = 1.097 x 10^7 m^{-1}.

TWO MARKS QUESTIONS WITH ANSWER

1. **Name the two quantised conditions proposed by Bohr in the atom model.**

   Ans: Bohr proposed i) quantised of energy states related to the transition of electrons from one orbit to another. ii) quantisation of orbit or angular momentum.

2. **Write the mathematical conditions for quantisation of orbits and energy states.**

   Ans: i) $mvr=\frac{nh}{2\pi}$ → quantisation of angular momentum

   ii) $E_2 - E_1 = h\surd$ → quantisation of energy states and resulting transition.

3. **Write the expression for the radius of n^th^ orbit. Give the meaning of symbols used.**

Ans: r = $\frac{\varepsilon_o n^2 h^2}{\pi m Z e^2}$, where ‘r’ is radius, n is principal Quantum number , h is Planck’s constant , m is the mass of electron , Z atomic number and e is quantised unit of charge and ϵ_o absolute permittivity for air or free space.

4. **Give the expression for velocity of an electron in the n^{th} orbit. Give the meaning of symbols used.**

Ans: v $= \frac{Ze^2}{2\varepsilon_o nh}$, where Z atomic number , e is charge, n is principle quantum number, h is Planck constant, ϵ_o is absolute permittivity.

5. **Write the formula for the wave number of a spectral line.**

Ans: $\bar{\upsilon} = \frac{me^4}{8\varepsilon_0^2\, ch^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ or $\bar{\upsilon}$ =R $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

6. **What is the expression for the Rydberg’s constant ? Give the meaning of the symbols used.**

Ans: R = $\frac{me^4}{8\varepsilon_0^2\, ch^3}$ where m-mass of the electron, e-charge on the electron, c-speed of light and h- Planck’s constant.

7. **Write the formula for wave number of the spectral lines of Lyman series.**

Ans: Lyman Series consists of spectal lines corresponding to the transition of an electron from higher energy orbits to the first orbit . i.e., n=1 and n_2=3,4,5……∞

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

8. **Write the formula for wave number of the spectral lines of Balmer series.**

Ans: Balmer Series consists of spectral lines emitted during transistions of electron from higher energy orbits to the second orbit. i.e., n_1=2 and n_2=3,4,5…..∞

$$\bar{\upsilon} = R\left(\frac{1}{4} - \frac{1}{n_2^2}\right) = R\left(\frac{n_2^2-4}{4n_2^2}\right)$$

9. **Mention any two demerits of Bohr’s Theory.**

Ans: i) The theory is applicable only for hydrogen atom.

ii)The relativistic variation of mass is not taken into account in the theory.

iii)The fine structure of spectral lines cannot be accounted for.

iv) The theory fails to account for relative intensities of spectral lines.

10. How does Rydberg's constant vary with atomic number?

Ans: $R = Z^2 R_H$, where Z= atomic number. R is directly proportional to Z^2

R_H = Rydberg's constant for hydrogen atom.

11. What is the value of ionization potential of ^4_2He atom?

Ans: I.E = -(13.6 eV)Z^2

put Z = 2

∴ I.E = -13.6$(2)^2$ Ev = -54.4 eV.

∴ Ionisation potential = -54.4 V.

12. Name the physicists who for the first time verified the wave nature of electrons.

Ans: C.J. Davisson and L.H. Germer verified the wave nature of electrons.

THREE MARK QUESTIONS WITH ANSWER

1. Explain briefly 1)Bohr's Quantisation rule and 2) Bohr's frequency condition.

Ans: 1) The radius of the allowed electron orbits is determined by Quantum condition which states that the orbit angular momentum of the electron about the nucleus is an integral multiple of $\frac{h}{2\pi}$ .According to Bohr's postulate

$$mvr = n\left(\frac{h}{2\pi}\right).$$

2) The atom radiates energy only when an electron jumps from one stationary orbit of higher energy to another of lower energy $E_2 - E_1 = hv$ or

$$v = (E_2 - E_1)/h.$$

2. Write de-Broglie wavelength associated with 3rd and 4th orbit in Bohr's atom model .

Ans: According to quantisation rule of Bohr's model

$mvr = \left(\frac{nh}{2\pi}\right)$

i.e., linear momentum $p=\left(\frac{nh}{2\pi}\right)$

but from de-Broglie's wave concept of moving matter $p = \frac{h}{\lambda}$,i.e $\lambda = \frac{h}{mv}$

or $\lambda = \frac{h}{nh}.\, 2\pi r$

or $\lambda = \frac{2\pi r}{n}$

For 3rd and 4th orbit, $\lambda_3 = \frac{2\pi r_3}{3}$ and $\lambda_4 = \frac{2\pi r_4}{4}$

3. Give de-Broglie's explanation of quantisation of angular momentum as proposed by Bohr.

Ans: The condition for stationary wave formation is that the total distance travelled between the nodes(two) up and down or given path is integral multiple of 'λ'

i.e ., $2\pi r_n = n\lambda$ where, n=1,2,3,…….

But $\lambda = \frac{h}{mv}$ (from de-Broglie's hypothesis)

$2\pi r_n = \frac{nh}{mv_n}$

$mv_n r_n = n\left(\frac{h}{2\pi}\right)$

i.e integral multiple of $\left(\frac{h}{2\pi}\right)$ should be equal to the angular momentum of electron in the orbit.

4. **What are hydrogenic atoms?**

Ans: Hydrogenic (Hydrogen like) atoms are the atoms consisting of a nucleus with positive charge '+Ze' and a single electron. Here 'Z' is atomic mass number and 'e' is the quantised unit of charge.

E.g., singly ionised helium, doubly ionised lithium.

5. **Relate KE, PE and total energy of electron of an hydrogenic atom.**

Ans: i) Potential Energy = 2 times the total energy.

ii) Kinetic Energy of an electron = Minus of total energy.

where ,total energy is negative and E= - $\frac{Z^2me^2}{8\varepsilon_o^2n^2h^2}$

For H_2 atom , Z=1

For H_2 like atoms , charge on the nucleus = +Ze

6. **How is frequency of radiation different from that of frequency of electron in its orbit?**

Ans: i) For radiation frequency ν= $\frac{E_1 - E_2}{h}$

$\nu = Z^2Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

where n_2 = higher orbit and n_1= lower orbit.

7. **Why do we use gold in Rutherford's α-particle scattering experiment?**

Ans: The reasons are i) gold is malleable ii) Gold nucleus is heavy and produce large deflections of α – particles.

8. **Using Balmer empirical formula, obtain the wavelengths of H_α , H_β , H_γ, H_σ … … … H_∞.**

Ans: Balmer empirical formula is given by $\frac{1}{\lambda}$ = R$\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

For H_α line, put n=3, $\frac{1}{\lambda_\alpha}$ = R$\left(\frac{5}{36}\right)$ where R = 1.097 x 10^7 m^{-1} this gives λ_α=656.3nm.

For H_α line, put n=3, $\frac{1}{\lambda_\beta}$ = R$\left(\frac{3}{16}\right)$, this gives H_β line λ_β = 486.1nm

Similarly for λ_γ, put n=5; H_γ = λ_γ =434.1nm

for λ_δ, put n=6; H_δ = λ_δ =434.1nm

for λ_∞,called series limit,put n=∞; λ_∞ = 364.6nm

FIVE MARKS QUESTIONS WITH ANSWER

1. **State the postulates of a Bohr's theory of hydrogen atom.**

Ans: i) An electron cannot revolve round the nucleus in any arbitrary orbit. Only Certain orbits are permitted. Electron does not radiate energy in stationary

ii) The radius of the allowed electron orbits is determined by the quantum condition. It stated that the orbital angular momentum of electron about the nucleus is integral multiple of $\frac{h}{2\pi}$. According to Bohr's postulate $mvr=n\left(\frac{h}{2\pi}\right)$.

iii) The atom radiation the energy only when an electron Jumps from higher energy to lower energy. If E_1 and E_2 are lower and higher energies and $\nu=\frac{E_2-E_1}{h}$

2. Derive an expression for the radius of n^th Bohr's orbit of H_2 atom.

Ans: Consider an atom of atomic number Z. The charge on its nucleus is +Ze. Let an electron of mass m and charge '-e' revolve round the nucleus in a circular orbit.

Let v be its velocity.

The coulomb's electrostatic force of attraction between the electron and the nucleus is = $\frac{1}{4\pi\varepsilon_o}\left[\frac{Ze^2}{r^2}\right]$

This provides the centripetal force $\frac{mv^2}{r}$ needed for orbital motion of electron

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_o}\left[\frac{Ze^2}{r^2}\right]$$

or

$$mv^2r = \frac{Ze^2}{4\pi\varepsilon_o}$$

From Bohr's Quantization rule, for the n^th orbit,

We have, $mvr = \frac{nh}{2\pi}$

Squaring Equation (2)

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

Dividing Equation (3) by Equation (1)

$$\frac{m^2v^2r^2}{mv^2r} = \frac{n^2h^2}{4\pi^2} \times \frac{4\pi\varepsilon_o}{Ze^2}$$

i.e ., $mr = \frac{\varepsilon_o n^2h^2}{\pi Ze^2}$

$$\therefore \quad r = \frac{\varepsilon_o n^2h^2}{\pi mZe^2}$$

For H_2 atom put Z = 1 and for I orbit put n=1 and r =. $\frac{\varepsilon_o h^2}{\pi m e^2}$

3. Obtain an expression for the energy of an electron in the n^{th} orbit of hydrogen atom in terms of the radius of the orbit and absolute constants.

Ans: Consider an electron of mass *m* and charge –e revolving round the nucleus of an atom of atomic number Z in the n^{th} orbit of radius 'r'. Let v be the velocity of the electron. The electron possess potential energy because it is in the electrostatic field of the nucleus it also possess kinetic energy by virtue of its motion.

Potential energy of the electron is given by

E_p = (potential at a distance *r* from the nucleus)(-e)

$$= \frac{1}{4\pi\varepsilon_o}\left[\frac{Ze^2}{r}\right](-e)$$

$$E_p = -\frac{Ze^2}{4\pi\varepsilon_o r} \qquad ...(1)$$

Kinetic energy of the electron is given by

$$E_k = \frac{1}{2} mv^2 \qquad ...(2)$$

From Bohr's postulate

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_o}\left[\frac{Ze^2}{r}\right]$$

$$\therefore \quad mv^2 = \frac{Ze^2}{4\pi\varepsilon_o r}$$

Substituting this value of mv^2 in equation (2)

$$E_k = \frac{1}{2}\left(\frac{Ze^2}{4\pi\varepsilon_o r}\right)$$

Total energy of the electron resolving in the n^{th} orbit is given by $E_n = E_p + E_k$

$$E_n = -\frac{Ze^2}{4\pi\varepsilon_o r} + \frac{1}{2}\left(\frac{Ze^2}{4\pi\varepsilon_o r}\right) \qquad \text{Using (1) and (2)}$$

$$= \frac{Ze^2}{4\pi\varepsilon_o r}\left[\frac{-1}{1} + \frac{1}{2}\right] = \frac{Ze^2}{4\pi\varepsilon_o r}\left[\frac{-1}{2}\right]$$

$$E_n = -\frac{Ze^2}{8\pi\varepsilon_o r}$$

The radius of n^{th} permitted orbit of the electron is given by $r = \frac{\varepsilon_o n^2 h^2}{\pi m Z e^2}$

Substituting this value of r in equation (4).

$$E_n = -\frac{Ze^2}{8\pi\varepsilon_o} \times \frac{\pi m Z e^2}{\varepsilon_o n^2 h^2}$$

i.e., $E_n = \frac{-Z^2 m e^4}{8\varepsilon_0^2 n^2 h^2}$ for hydrogen like atoms.

For hydrogen atom Z = 1.

∴ Total energy of the electron in the n^{th} orbit of hydrogen atom is $E_n = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2}$

4. Give an account of the spectral series of hydrogen atom.

Ans: Hydrogen atom has a single electron. Its spectrum consists of series of spectral lines.

Lyman series : Lyman Series consists of spectral lines corresponding to the transition of an electron from higher energy orbits n = 1 and $n_2 = 2,3,4\ldots\infty$

These lines belong to Ultraviolet region.

Balmer series: Balmer series consists of spectral lines emitted during transitions of electrons from higher energy orbits to the second orbit. $n_1 = 2$ and $n_2 = 3,4,5\ldots\infty$ .These lines lie is the visible region.

Paschen series : Paschen series consists of spectral lines emitted when electron jumps higher energy orbits to the third orbit $n_1 = 3$ and $n_2 = 4,5,6\ldots\infty$.These lines lie in the infrared region.

Brackett series : Brackett series consists of spectral lines emitted during transitions of electrons from higher energy orbits to fourth orbit. $n_1 = 4$ and $n_2 = 5,6,7\ldots\infty$

Pfund series : Pfund series consists spectral lines emitted during transition of electrons from higher energy orbits to the fifth orbit. . $n_1 = 5$ and $n_2 = 6,7,8\ldots\infty$.

These lines lie in infrared region . The transition from $(n_1 + 1)$ to n_1 corresponding to I^{st} member or longest wavelength of the series. The transition from ∞ (infinity) state to 'n_1' state corresponds to the last number or series limit or shortest wavelength of the series.

5. Explain energy level diagram of hydrogen atom.

Ans: The total energy of an electron in its orbit for an hydrogen atom

$E = \frac{-13.6}{n^2}$ eV .

Where 'n' is known as the principle quantum number whose value

n =1,2,3….

$E_1 = \frac{-13.6}{1^2}$ eV = -13.6 eV

$E_2 = \frac{-13.6}{2^2}$ eV = -3.4 eV

$E_3 = \frac{-13.6}{3^2}$ eV = -1.511 eV

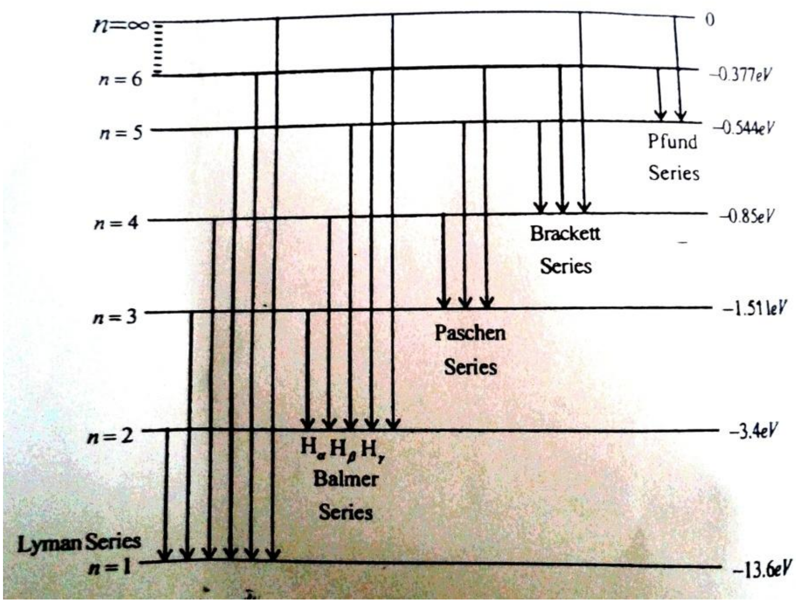
$E_4 = \frac{-13.6}{4^2}$ eV = -0.85 eV

$E_5 = \frac{-13.6}{5^2}$ eV = -0.544 eV

$E_6 = \frac{-13.6}{6^2}$ eV = -0.377 eV

And $E_\infty = 0$

The energy level diagram represents different energy states with an increasing energy. The transition of electrons from higher energy states to lower energy states results in various levels of radiations classified into ultra violet, visible and invisible spectrum of radiation is illustrated below.



6. Derive an expression for the frequency of spectral series by assuming the expression for energy.

Ans: When atom in the excited state returns to normal state , results in transition.

$$E_2 - E_1 = h\nu = \frac{hc}{\lambda}$$

i.e, $$\frac{1}{\lambda} = \left(\frac{1}{hc}\right)(E2 - E1)$$

where, $$E_n = \frac{-Z^2 m e^4}{8\varepsilon_0^2 n^2 h^2}$$

hence $$\frac{1}{\lambda} = \frac{Z^2 m e^4}{8\varepsilon_0^2 h^3 c}\left(\frac{-1}{n_2^2} - \left(-\frac{1}{n_1^2}\right)\right)$$

i.e $$\frac{1}{\lambda} = \frac{Z^2 m e^4}{8\varepsilon_0^2 h^3 c}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

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

where , $R = \frac{m e^4}{8\varepsilon_0^2 h^3 c}$ is Rydberg's constant.

For H_2 atom, Z = 1

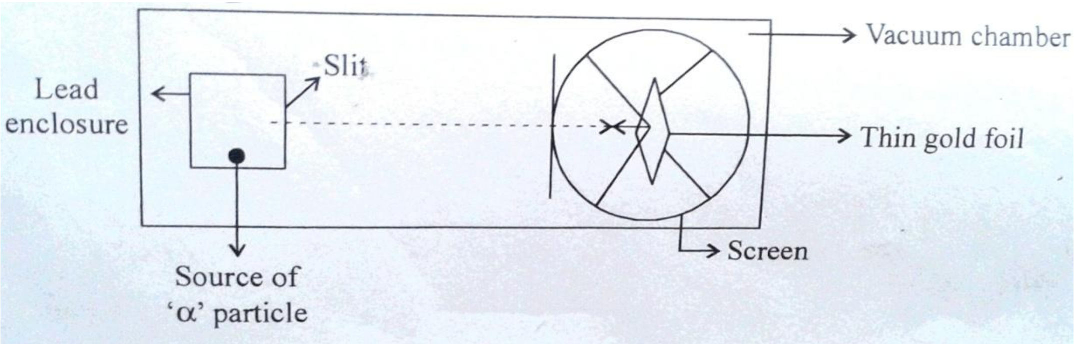
∴ Wave number $\bar{\upsilon} = \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ and frequency

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

Where $n_2 = n_1 + 1$, $n_1 + 2$, $n_1 + 3$,……….∞

7. **Outline the experiment study of α - scattering by a gold foil.**

Ans:



Geiger - Marsden α-scattering experiment

The source of α- particles are taken from α - decay of $^{214}_{83}Bi$. Gold foil used is of thickness 0.21 micron. The scattering α – particles were discovered by rotatable detector with a fluorescent flashes observed through the microscope. The intensity of α- particles is studied as the function of 'θ'

For a range value of I_p , α- particles travel straight because of small deflection.

For θ=180º , Ip = 0 , the α- particles when directed towards the centre (for a head – on collision) , it retraces the path.

8. **Give the experimental conclusions arrived by Rutherford in the α- scattering experiment.**

Ans: conclusions:

i)The entire mass of the atom is concentrated in the nucleus of an atom.

ii)The entire charge is concentrated in the nucleus rather than distributing throughout the volume of the atom.

iii) The size of the nucleus is estimated to be of the order of 10^{-15} m and atom of the order 10^{-10} m.

iv) The size of the electron is negligibly small and space between the electron and nucleus is almost void.

v) Atom as a whole is electrically neutral.

vi) Electron is acted upon by a force and hence it is not in the state of static equilibrium.

vii) To explain the H_2 – spectrum Rutherford proposed radiating circular orbits and for the stability he assumed that the centripetal force is balanced by electrostatic force of attraction.

i.e., $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\left[\frac{Ze^2}{r^2}\right]$
