



Chapter # 20

Atomic Spectra



Learning Objectives

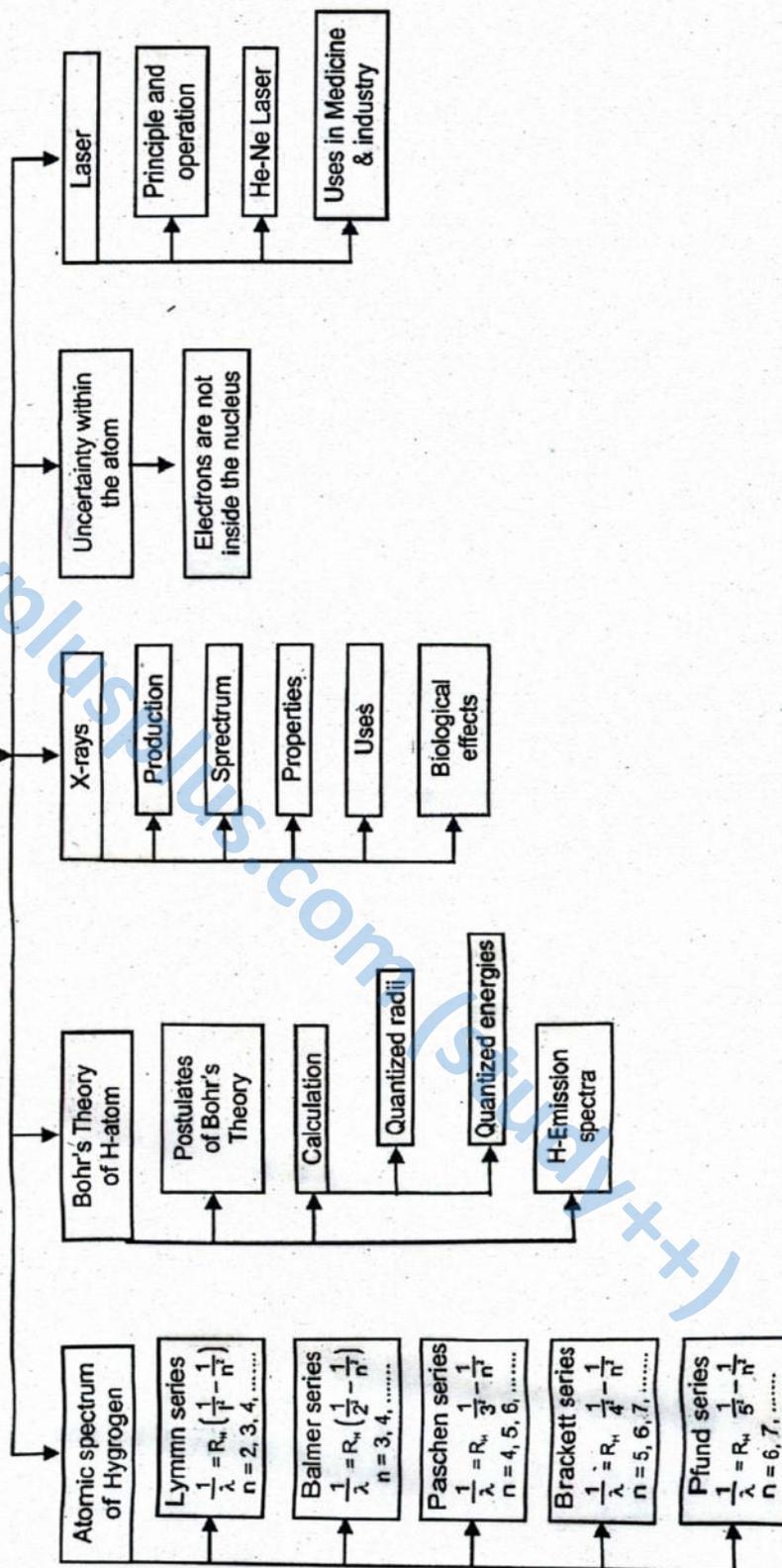
- Know experimental facts of hydrogen spectrum.
- Describe Bohr's postulates of hydrogen atom.
- Explain hydrogen atom in terms of energy levels.
- Describe de-Broglie's interpretation of Bohr's orbits.
- Understand excitation and ionization potentials.
- Describe uncertainty regarding position of electron in the atom.
- Understand the production, properties and uses of X-rays.
- Describe the terms spontaneous emission, stimulated emission, metastable states and population inversion.
- Understand laser principle.
- Describe the He-Ne gas laser.
- Describe the application of laser including holography.



CONCEPT MAP

ATOMIC STRUCTURE

The branch of Physics which deals with extra-nuclear part of an atom and various phenomena associated with it



The branch of physics which deals with the production, measurement, and interaction of electromagnetic radiation emitted or absorbed by atoms is called **spectroscopy**. So, it is the study of spectra produced by atoms.

Types of Emission Spectra:

In general, there are three types of spectra:

- (i) Continuous spectrum
- (ii) Band spectrum
- (iii) Line or discrete spectrum

(i) Continuous Spectrum:

A radiation spectrum in which the frequencies of the radiations emitted by the atoms of a substance are so close to each other that they give continuous row of overlapping images is called a continuous spectrum.

Example

Black body radiation spectrum is the example of continuous spectra.

(ii) Band Spectrum:

A spectrum that appears as a number of bands of emitted or absorption radiations is called band spectrum.

Example

Molecular spectrum is the example of band spectrum.

(iii) Line or discrete spectrum:

A spectrum consisting of discrete lines corresponding to single wavelengths of emitted radiation is called as line spectrum.

Example

Atomic spectra are examples of discrete or line spectra.

For Your Information

Different types of spectra



(a) Continuous spectrum



(b) Line spectrum



(c) Band spectrum

Q.1 What is Atomic Spectrum? Discuss Different Series in Visible Region of Electromagnetic Spectrum?

Ans.

ATOMIC SPECTRUM

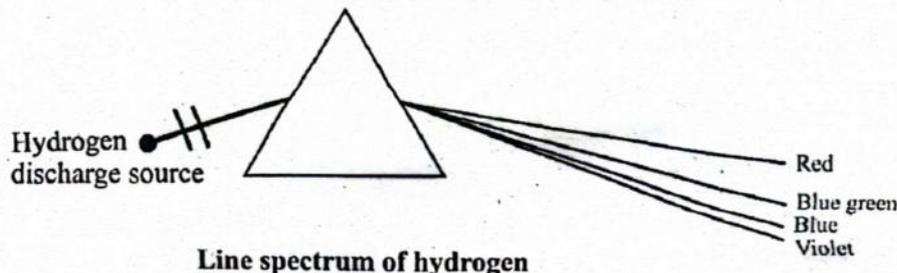
A spectrum of radiation due to transitions between energy levels in an atom (may be due to absorption or emission) is called atomic spectrum.

When an atomic gas or vapour at much less than atmospheric pressure is suitably excited by passing electric current through it, the spectrum of emitted radiation contains certain wavelengths only which appear in the form of sharp lines on the screen. This type of spectrum is called line spectrum.

An idealized arrangement is shown in figure to observe the atomic spectrum. But an actual spectrometer uses diffraction grating for better results. If we use a narrow slit of rectangular shape then the pattern on the screen is in form of line. So the spectrum is called line spectrum.

Identification of Elements

Every element has its own specific spectrum that contains certain wavelengths which describe the characteristic of an element. In this way, different elements are identified.



Spectral Series

The spectrum of an element contains certain wavelengths that show definite regularities. These regularities are classified into certain groups called spectral series.

1. Balmer Series

In 1885, the first spectral series for hydrogen was identified by J.J. Balmer. The mathematical results were based on his study in the **visible** region of electromagnetic spectrum. In 1896, Rydberg expressed the results obtained by Balmer in mathematical form as,

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \quad \text{where } n=3,4,5,\dots$$

R_H is the Rydberg's constant and its value is $1.0974 \times 10^7 \text{ m}^{-1}$

Other series for hydrogen atom

2. Lyman Series Lyman series lie in **ultraviolet** region and its wave lengths are given by,

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

where $n = 2, 3, 4, \dots$

Paschen Series

Paschen series lies in the **infrared** region and its wave length is given by,

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

where $n = 4, 5, 6, \dots$

Bracket Series

Paschen series lies in the **infrared** region and its wave length is given by,

$$\frac{1}{\lambda} = R_H \left(\frac{1}{4^2} - \frac{1}{n^2} \right)$$

where $n = 5, 6, 7, \dots$

Pfund Series

Pfund series lies also in the **infrared** region and its wave length is given by,

$$\frac{1}{\lambda} = R_H \left(\frac{1}{5^2} - \frac{1}{n^2} \right)$$

where $n = 6, 7, 8, \dots$

General Formula

From above formulas, we can write

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

Where $n = p + 1, p + 2, p + 3, \dots$

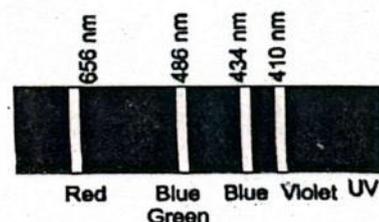
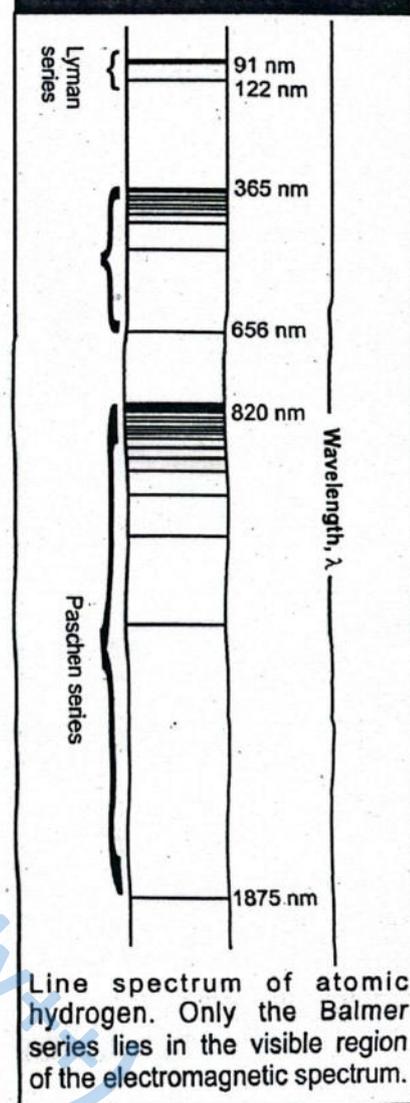


Fig. 20.2

For Your Information



Q.2 Give the Postulates of Bohr's Atomic model. How did de-Broglie deduced Bohr's second postulate?

RWP - 2017, GRW - 2017, FEDERAL - 2016, SGD - 2016

BOHR'S MODEL OF HYDROGEN ATOM

In 1913 Bohr proposed the atomic model for Hydrogen atom to explain the empirical results of Rydberg. He used the classical as well as quantum physics for his explanation. His semi-classical theory based upon following postulates.



Do you know?

Helium was identified in the Sun, using spectroscopy, before it was discovered on earth.

Postulate I: (Stationary state postulate)

An electron, bound to the nucleus in an atom can move around the nucleus in certain circular orbits without radiating. These orbits are called the discrete stationary states of the atom.

Postulate II: (Quantization of orbital angular momentum)

Only those stationary orbits are allowed for which the orbital angular momentum is equal to an integral multiple of $\frac{h}{2\pi}$. i.e.

$$mvr = \frac{nh}{2\pi} \quad \text{where } n = 1, 2, 3, \dots$$

n is called principle quantum number, m and v are the mass and velocity of orbiting electron respectively and h is the Plank's constant.

Postulate III: (Quantization of energy)

Whenever an electron makes a transition that is, jumps from high energy state E_n to a lower energy state E_p , a photon of energy hf is emitted so that

$$hf = E_n - E_p \quad \text{where } f = c/\lambda$$

de BROGLIE'S INTERPRETATION OF BOHR'S ORBITS

Consider a string of length ' ℓ ' as shown in Fig. (a)

If stationary waves are set up in a stretched string. Then we can write

$$\ell = n\lambda \quad (1)$$

Where n is an integer.

Let the string is bent into circle of radius r for $n = 3$ and $n = 6$ as shown in figure.

If $2\pi r$ is the circumference of the circle, then

$$\ell = 2\pi r \quad (2)$$

Comparing equations (1) and (2), we have

$$2\pi r = n\lambda$$

$$\text{or } \lambda = \frac{2\pi r}{n} \quad (3)$$

According to de-Broglie

$$\lambda = \frac{h}{p} \quad (4)$$

Comparing equation (3) and (4), we get

$$\frac{h}{p} = \frac{2\pi r}{n}$$

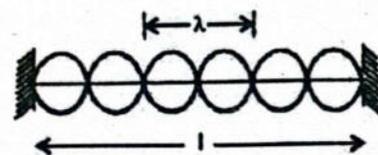
$$\text{or } \frac{h}{mv} = \frac{2\pi r}{n}$$

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

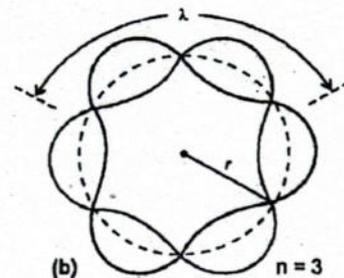
Which is the second postulate of Bohr's atomic model.

Note

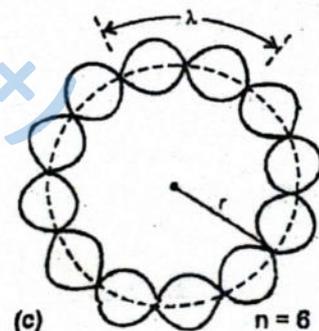
At the time of formulation of Bohr's theory, there was no justification for the first two postulates, while 3rd postulate has some roots in plank's thesis.



(a) Stationary wave for $n = 3$ on a string.



(b) $n = 3$



(c) $n = 6$



Ans.

QUANTIZED RADII

Consider a hydrogen atom in which electron moving with velocity V_n in a circular orbit of radius r_n .

Coulomb's force between electron and a proton may be expressed as,

$$F_e = k \frac{e \cdot e}{r_n^2}$$

Or

$$F_e = \frac{ke^2}{r_n^2}$$

where k is the coulomb's constant and e is the charge on electron as well as proton.

As electron is revolving around the nucleus, so the centripetal force acting on it, is given by

$$F_c = \frac{mv_n^2}{r_n}$$

Coulomb's force provides the necessary centripetal force to revolve around the nucleus. So

$$F_c = F_e$$

$$\frac{mv_n^2}{r_n} = \frac{ke^2}{r_n^2}$$

or

$$mv_n^2 = \frac{ke^2}{r_n} \quad \text{--- (1)}$$

According to second postulate of Bohr model,

$$mv_n r_n = \frac{nh}{2\pi} \quad \text{--- (2)}$$

or

$$v_n = \frac{nh}{2\pi m r_n}$$

So equation (1) becomes

$$m \left(\frac{nh}{2\pi m r_n} \right)^2 = \frac{ke^2}{r_n}$$

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

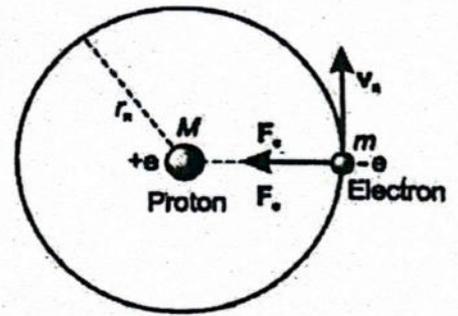
or

$$r_n = \frac{n^2 h^2}{4\pi^2 k e^2 m}$$

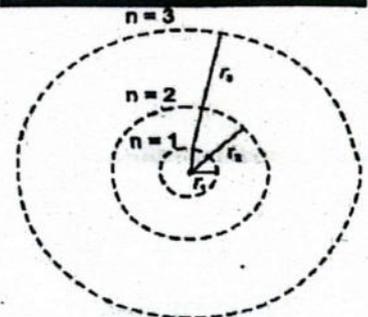
$$r_n = n^2 \left(\frac{h^2}{4\pi^2 k e^2 m} \right) \quad \text{--- (3)}$$

This is the radius of n th allowed orbit

Since
$$\frac{h^2}{4\pi^2 k e^2 m} = \frac{(6.625 \times 10^{-34})^2}{4(3.14)^2 (9 \times 10^9) (1.6 \times 10^{-19})^2 (9.11 \times 10^{-31})}$$



For Your Information



The first Bohr orbit in the hydrogen Atom has a radius $r = 5.3 \times 10m$. The second and third Bohr orbits have radii $r_2 = 4r_1$ and $r_3 = 9r_1$ respectively.

$$= 0.053 \times 10^{-9} \text{ m}$$

$$= 0.053 \text{ nm}$$

So, equation (3) becomes

$$r_n = n^2 \times 0.053 \text{ nm} \quad (4)$$

Radius of first Bohr orbit

Now for first orbit, $n = 1$

Thus $r_1 = (1)^2 \times 0.053$
 $r_1 = 0.053 \text{ nm}$

Hence, equation (4) becomes

$$r_n = n^2 r_1 \quad (5)$$

Radii of different Bohr's stationary orbits

The radii of different Bohr's stationary orbits are given by

$$r_n = r_1, 4r_1, 9r_1, 16r_1, \dots$$

Speed of Electron

The speed of electron in n th orbit can be obtained by putting the value of r_n from equation (3) in (2), we get

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

$$v_n = \frac{nh}{2\pi m r_n}$$

$$v_n = \frac{nh}{2\pi m \left(\frac{n^2 h^2}{4\pi^2 k e^2 m} \right)}$$

$$v_n = \frac{2\pi k e^2}{nh} \quad (6)$$

Q.4 Derive an expression for the energy of electron revolving in n th orbit of H-atom.

Ans.

Let us calculate the total energy E_n of an electron orbiting in Bohr orbit (i.e., first orbit).

The total energy of an electron (E_n) in an orbit is equal to the sum of its kinetic energy (K.E.) and potential energy (U) i.e.,

$$E_n = \text{K.E.} + U$$

Kinetic Energy

As K.E may be expressed as

$$\text{K.E.} = \frac{1}{2} m v_n^2 \quad \left[\because \text{from equation (1)}, m v_n^2 = \frac{k e^2}{r_n} \right]$$

$$\text{K.E.} = \frac{k e^2}{2 r_n} \quad (6)$$

Potential Energy

The potential energy may be expressed as the work done for displacing the electron through r_n from nucleus.

As

$$U = -q\Delta V$$

$$= -e\Delta V$$

$$= -e \frac{k e}{r_n}$$

FOR YOUR INFORMATION

n th excited state means $(n+1)$ th orbit.

So, P.E. becomes

$$U = -\frac{k e^2}{r_n} \quad (7)$$

Total Energy

Total energy may be expressed as,

$$E_n = U + K.E$$

Putting values, we get

$$E_n = -\frac{ke^2}{r_n} + \frac{ke^2}{2r_n}$$

$$E_n = \frac{ke^2}{r_n} \left(-1 + \frac{1}{2}\right)$$

$$E_n = -\frac{ke^2}{2r_n}$$

$$E_n = -\frac{ke^2}{2\left(\frac{n^2 h^2}{4\pi^2 k m e^2}\right)} \quad \left(\because r_n = n^2 \left(\frac{h^2}{4\pi^2 k e^2 m}\right)\right)$$

$$E_n = -\left(\frac{2\pi^2 k^2 m e^4}{h^2}\right) \frac{1}{n^2}$$

$$E_n = -\frac{E_0}{n^2}$$

where

$$E_0 = \frac{2\pi^2 k^2 m e^4}{h^2} = \text{constant}$$

$$E_0 = \frac{2\pi^2 k^2 m e^4}{h^2} = \frac{2(3.14)^2 (9 \times 10^9)^2 (9.11 \times 10^{-31})(1.6 \times 10^{-19})^4}{(6.63 \times 10^{-34})^2}$$

$$E_0 = +2.17 \times 10^{-18} \text{ J}$$

$$E_0 = \frac{+2.17 \times 10^{-18}}{1.6 \times 10^{-19}} \text{ eV}$$

$$E_0 = +13.6 \text{ eV}$$

$$E_n = -\frac{E_0}{n^2} \quad \text{----- (9)}$$

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

For different values of principal quantum number 'n', we get the allowed energy levels of hydrogen atom to be

$$E_n = -E_0, -\frac{E_0}{4}, -\frac{E_0}{9}, -\frac{E_0}{16}, \dots$$

These are called quantized energy status or allowed energy states.

Ground State

When the electron is in its lowest energy state (i.e. $n = 1$), it is said to be in its ground state.

Excited State

When the electron is in the higher orbits it is said to be in excited state.

Excitation potential

The atom may be excited by collision with some externally accelerated electrons. *The potential through which an electron should be accelerated is called excitation potential.*

Do You Know?

The orbital electrons have specific amount of energies where as free electrons may have any amount of energy.

FOR YOUR INFORMATION

The energy of the electron in an orbit always negative,

Do You Know?

Photon must have energy exactly equal to the energy difference between the two shells for excitation with K.E greater than the required difference can excite the gas atom.



Ionized State

When the electron is isolated from the atom then atom is said to be ionized. In ionized state $E_{\infty} = 0$.

Ionization potential

The potential needed to lift up the electron to the infinite state is called the ionization potential.

Q.5 Explain hydrogen emission spectrum on the basis of Bohr model of hydrogen atom.

Ans.

HYDROGEN EMISSION SPECTRUM

Suppose that the electron in hydrogen atom is in the excited state with energy E_n and makes a transition to a lower energy state E_p

So $E_p < E_n$.

Then,

$$hf = E_n - E_p$$

where $E_n = -E_0 / n^2$ and $E_p = -E_0 / p^2$

$$hf = -\frac{E_0}{n^2} - \left(-\frac{E_0}{p^2} \right)$$

So
$$\frac{hc}{\lambda} = E_0 \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$$

$$\frac{1}{\lambda} = \frac{E_0}{hc} \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$$

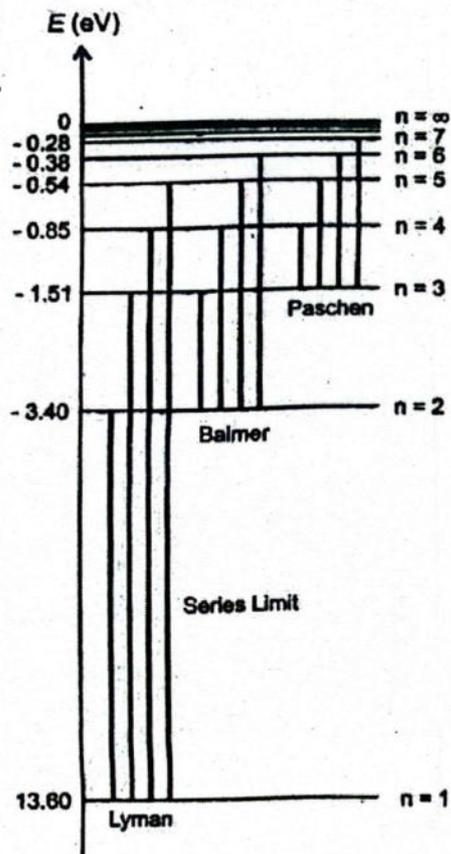
Or
$$\frac{1}{\lambda} = R_H \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$$

where
$$R_H = \frac{E_0}{hc} = \frac{13.6\text{eV}}{(6.63 \times 10^{-34})(3 \times 10^8)}$$

$$R_H = \frac{E_0}{hc} = \frac{(13.6)(1.6 \times 10^{-19})}{(6.63 \times 10^{-34})(3 \times 10^8)}$$

$$R_H = 1.0974 \times 10^7 \text{ m}^{-1}$$

The different energy levels for hydrogen atoms are shown in figure.



Energy level diagram for the hydrogen atom.

MCQ's From Past Board Papers

- If electrons jumps from second orbit to first orbit in hydrogen atom it emits photon of: (Swl 2018, Shl 2015)
(A) 3.40eV (B) 10.20 eV (C) 13.6eV (D) 3.8 eV
- The value of Rydberg's constant is (AJK, D.G.Khan 2018, Grw 2017, Sgd 2015 G - I)
(A) $1.09 \times 10^7 \text{ m}^{-1}$ (B) $1.09 \times 10^8 \text{ m}^{-1}$ (C) $1.09 \times 10^9 \text{ m}^{-1}$ (D) $1.09 \times 10^{10} \text{ m}^{-1}$
- Which of the following series lies in the ultraviolet region? (Fsd 2014, Lhr 2012, Mirpur 2016, Grw 2013 G I)
(A) Lyman series (B) Balmer series (C) P fund series (D) Braecket series
- The value of radius of 1st Bohr's orbit is (Mtn 2017 G I, D.G.Khan 15 Group I, 16 Group I)
(A) 0.53 nm (B) 0.053 nm (C) 0.0053 nm (D) 0.00053 nm
- Radius of 3rd Bohr orbit in hydrogen atom is greater than radius of 1st orbit by _____. (Lhr 2010, Fed 2012)
(A) 2 (B) 3 (C) 4 (D) 9
- If the ionization energy of hydrogen atom is 13.6 eV, its ionization potential will be _____. (Fed 2013)
(A) 13.6 V (B) 136.0 V (C) 3.4 V (D) None of these
- Energy of the 4th orbit in hydrogen atom is: (Swl 2017, Bwp 2017 G I, Lhr 2014 G I)
(A) -25.51 eV (B) -3.50 eV (C) -13.6 eV (D) -0.85 eV

8. In which region of electromagnetic spectrum of Hydrogen, the balmer series lies?
(D.G.Khan 2018, Swl 2014, Mirpur 2013, Fsd 2017, Lhr 2010, 14, 16 G I, Grw 2014, 2016, Fsd 2015, Fed 2011)
- (A) Infrared (B) Visible (C) Ultraviolet (D) Far ultraviolet
9. Speed of the electron in the first Bohr's orbit is:
(A) 2.19×10^6 m/s (B) 2.19×10^{-6} m/s (C) 2.19×10^6 cm/s (D) 2.19×10^{-6} m/s
(Rwp 2014, D.G.Khan 2014)
10. The unit of R_H (Rydberg's constant) is:
(A) ms^{-1} (B) m (C) m^2 (D) m^{-1}
(Azad Kashmir 2017, Sgd 2014, Rwp 2015)
11. The shortest wave length in Bracket Series have wave length:
(A) $\frac{16}{R_H}$ (B) $\frac{R_H}{16}$ (C) $16R_H$ (D) $4R_H$
(Lhr 2016Sgd 2014)
12. The speed of an electron in nth orbit is given as:
(A) $4\pi^2ke^2/nh$ (B) $2\pi ke^2/nh$ (C) $4\pi ke/n^2h^2$ (D) $2\pi^2ke^2/nh$
(Bwp 2015, Lhr 2016)
13. The relation between Rydberg constant ' R_H ' and ground state energy ' E_0 ' is given by:
(A) $R_H = \frac{E_0}{hc}$ (B) $R_H = \frac{he}{E_0}$ (C) $E_0 = \frac{R_H}{he}$ (D) $R_H = E_0 he$
(Grw 2015, Lhr 2010)
14. Atomic spectra are the examples of _____ spectra.
(A) Continuous (B) Line (C) Band (D) Mix
(Grw 2012, Lhr 2012, Bwp 2015)
15. The following gas was identified in the sun using spectroscopy:
(A) Hydrogen (B) Helium (C) Carbon (D) Nitrogen
(Rwp 2016)
16. The relation for paschen series is given as
(A) $\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$ (B) $\frac{1}{\lambda} = R_H \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$ (C) $\frac{1}{\lambda} = R_H \left(\frac{1}{4^2} - \frac{1}{n^2} \right)$ (D) $\frac{1}{\lambda} = R_H \left(\frac{1}{5^2} - \frac{1}{n^2} \right)$
(Sgd 2016 Group I)
17. Hydrogen atom spectrum does not lie in
(A) Ultraviolet region (B) Visible region (C) Infra-red region (D) X-ray region
(Lhr 2018, D.G.Khan 2016 Group II)
18. The radius of 10^{th} orbit in hydrogen atom is:
(A) 0.053 nm (B) 0.53 nm (C) 5.3 nm (D) 53 nm
(Rwp 2015)
19. First spectral series of Hydrogen atoms was discovered by
(A) Lyman (B) Rydberg (C) Balmer (D) Paschen
(D.G.Khan 2017 G II)
20. Second postulate of Bohr's atomic model is
(A) $mvr = \frac{nh}{2\pi}$ (B) $mvr = 2\pi nh$ (C) $mv = \frac{nh}{2\pi}$ (D) $mvr = \frac{2\pi}{nh}$
(Sgd 2017 G II)
21. The radiations emitted from hydrogen filled discharge tube can be analyzed into:-
(A) Band Spectrum (B) Line Spectrum (C) Continuous Spectrum (D) Absorption Spectrum
(Mtn 2017 G II)
22. For Panchen series the value of n starts from
(A) 2 (B) 4 (C) 6 (D) 8
(Rwp 2017)
23. The longest wavelength of Paschen series is:
(A) 656 nm (B) 1094 nm (C) 1875 nm (D) 2000 nm
(Lhr GI 2018)
24. The first orbit in the Hydrogen Atom has a radius:
(A) 5.3×10^{-11} m (B) 5.3×10^{11} m (C) 3.5×10^{-11} m (D) 3.5×10^{11} m
(Bwp GI 2018)
25. An electron in H-atom is excited from ground state to $n = 4$. How many spectral lines are possible in this case?
(A) 6 (B) 5 (C) 4 (D) 3
(D.G.Khan GI 2018)
26. Paschen series lie in the
(A) far-ultraviolet region (B) visible region (C) infrared region (D) ultraviolet region
(Grw 2018)

ANSWER KEY'S

1.	B	2.	A	3.	A	4.	B	5.	D	6.	A	7.	D	8.	B	9.	A	10.	D
11.	B	12.	D	13.	A	14.	B	15.	B	16.	B	17.	D	18.	C	19.	C	20.	A
21.	B	22.	B	23.	C	24.	A	25.	A	26.	C								

Q.6 Describe Briefly the Inner Shell Transitions and Characteristic X-rays.

Ans.

INNER-SHELL TRANSITIONS AND CHARACTERISTIC X-RAYS

When the transition of electron takes place in hydrogen or some other lighter atom, it results in the emission of spectral lines in the infrared, visible or ultraviolet region of electromagnetic spectrum due to small energy difference in transition levels.



Characteristic x-rays.

In heavy atoms, the inner shell electrons are tightly bound and a large amount of energy is required to excite them. After excitation, when an electron returns to its normal state, the photons of large energy are emitted known as x-rays. These x-rays consist of series of specific wave lengths or frequencies called *characteristic x-rays*.

Q.7 What are x-rays? Describe the production of x-rays. *GRW 2015, LHR 2016 G II, 2017 G I, Bwp 2014*

Ans.

PRODUCTION OF X-RAYS

X-rays were discovered by German physicist **Dr. Rontgen in 1895**. X-rays have very smaller wavelength or high frequency. *The production of x-rays is the reverse process of photoelectric effect.*

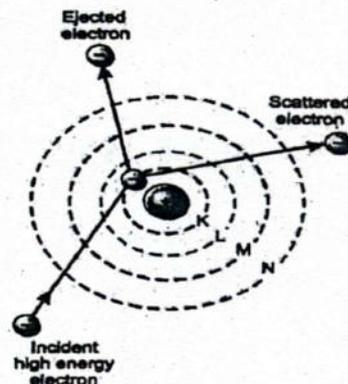
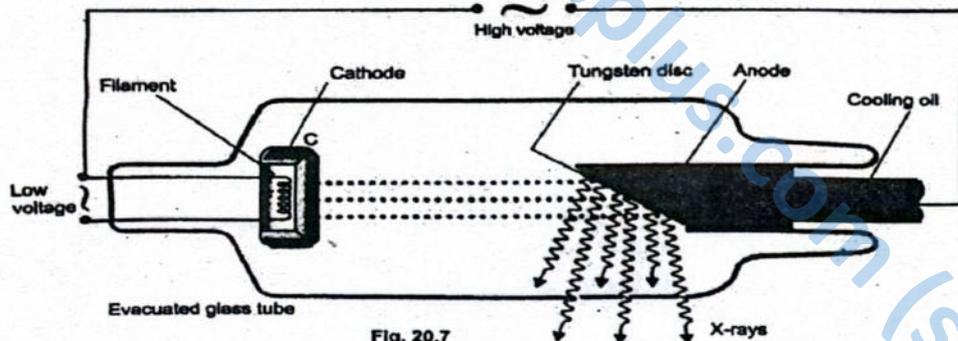
X-Rays

When fast moving electrons strike on a metal surface, photon of very high energy (i.e. high frequency) are emitted known as x-rays.

Production

The experimental arrangement consists of a high vacuum tube. When cathode is heated by a filament, it emits the electrons which are accelerated towards the anode. If V is the potential applied, then the K.E of electrons with which they collide the target is

$$K.E = Ve \quad (1)$$



For Your Information

For x-ray: Roentgen (1895)

- Wave length ranges from 0.1 \AA to 100 \AA .
- Energy ranges From 100 eV to 10^4 eV .

K_{α} x-rays

Suppose that a fast moving electron of energy Ve strike target of tungsten or any other heavy atom. Let an electron from K-shell of the atom is removed, it produces a vacancy of electron or hole in K shell.

The electron from L shell jumps to occupy the hole, thereby emitting a photon of energy $hf_{K_{\alpha}}$ called K_{α} x-rays and is given by

$$hf_{K_{\alpha}} = E_L - E_K$$

K_{β} x-ray

It is also possible that electron jumps from M-shell into K-shell. The photons emitted K_{β} x-ray with energy $hf_{K_{\beta}}$. So

$$hf_{K_{\beta}} = E_M - E_K$$

The photons emitted in such transition i.e., inner shell transition are called characteristic X-ray, because energies depend upon the type of target material.

For Your Information

Production of x-rays is the reverse process of *photoelectric effect*.



Ans.

CONTINUOUS X-RAY SPECTRUM

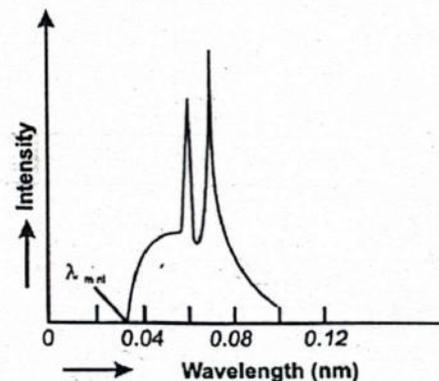
X-rays emitted in all directions with a continuous range of frequencies are called continuous X-rays. Spectrum is obtained due to deceleration of impacting electrons. The continuous spectrum is due to the effect known as bremsstrahlung or breaking radiation.

When a fast moving electron bombard the target, they are suddenly slowed down due to the electrostatic attractive force of nuclei of target. These impacting electrons emit radiation as they are decelerated by the target.

Since the rate of deceleration is so large that electrons lose all the K.E in the 1st collision, the whole K.E appears as the X-ray photons of energy hf_{\max} . i.e.,

$$K.E = hf_{\max} = \frac{hc}{\lambda_{\min}}$$

The wavelength λ_{\min} corresponds to frequency f_{\max} as shown in figure. Other electrons do not lose all their energy in their first collision. They may suffer a number of collisions before coming to rest. This will give rise the photons of smaller energy or x-rays of longer wave length. Thus the continuous spectrum is obtained due to the deceleration of impacting electrons.



Q.9 Describe the properties and uses of x-rays?

Rwp 2017

Ans.

PROPERTIES AND USES OF X-RAYS

X-rays have many practical applications in medicine and industry because X-rays can penetrate several centimeters into a solid matter, so they can be used to visualize the interior of the material which are opaque to ordinary light, such as fractured bones or defects in structural steel.

How to visualize an object (i.e.X-ray of an object)

To visualize the object, it is placed between an x-ray source and a large sheet of photo graphic film. The darkening of the film is proportional to the radiation exposure. A crack or air bulb allows greater amount of X-rays to pass. This appears as dark area on the photographic film. Shadow of bone appears lighter than the surrounding flesh.

It is due to the fact that bone contains greater proportions of the elements with high atomic number and so they absorbs great amount of X-rays than flesh. In flesh the number of light elements like carbon, hydrogen and oxygen greater, so these elements allow greater amount of incident X-ray to pass through them.

CAT SCANNER

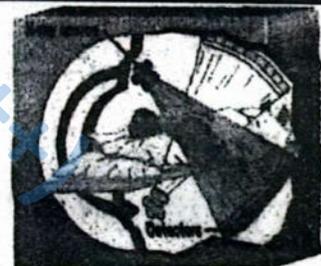
CAT stands for Computerized Axial Tomography. In CAT scanning, the x-ray source produces a thin fan shaped beam that is detected on the other side of the patient by an array of several hundred detectors in a line. Each detector measures absorption of X-ray along a thin line through the patient. The entire system is rotated around patient in a plane of the beam during a few seconds.

For Your Information



An X-ray picture of a hand.

Interesting Information

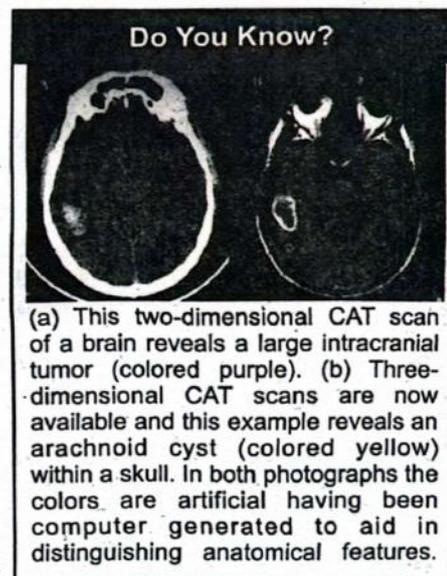


In CAT scanning a "fanned - out" array of X - ray beams is directed through the patient from a number of different orientations.

The changing reactions of the detector are recorded digitally; a computer processes this information and reconstructs a picture of different densities over an entire cross-section of subject. Density difference of the order of one percent can be detected with CAT-scans. Tumors and other much smaller anomalies can be detected.

BIOLOGICAL EFFECTS OF X-RAY

X-ray are ionizing radiations. They may cause damage to living tissue. As X-rays photons are absorbed in tissues, they break molecular bonds and create highly reactive free radicals (such as H and OH) which in turn can disturb the molecular structure of proteins and especially the genetic material. Young and rapidly growing cells are sensitive, hence X-rays are useful for selective destruction of cancer cells. The X-ray can cause cancer by excessive use. Even when the organism itself shows no apparent damage, excessive use may cause the changes in reproductive system that will affect the organism's offspring.



MCQ's From Past Board Papers

- Production of x-rays can be regarded as the inverse of
(Lhr 10, 2017, Grw 2013, Sgd 2015 G-II, Bwp 2016, Mtn 2016 G-I, Lhr 2011 G-I, 2012 G-II, 2015 G-I)
(A) Fair production (B) Compton effect (C) Photo electric effect (D) Annihilation of matter
- Photons emitted in inner shell transition are:
(Mtn 2015 G - I)
(A) Continuous X-rays (B) Discontinuous X-rays (C) Characteristic X-rays (D) Energetic X-rays
- When X-rays are passed through successive aluminum sheets, their hardness _____.
(Fed 2013)
(A) Decreases (B) Increases (C) Remains the same (D) None of these
- Which is not true for x-rays:
(Lhr 2014 G II)
(A) X-rays are not deflected by electric field (B) X-rays are polarized
(C) X-rays consist of electromagnetic waves (D) X-rays can be diffracted by grating
- X-rays can be:
(Grw 2014)
(A) reflected (B) diffracted (C) polarized (D) all of these
- X-rays are electromagnetic radiations having wavelength in the range
(Grw 2010)
(A) 10^{-12} m (B) 10^{-10} m (C) 10^{-18} m (D) 10^{-6} m
- The rest mass of X-rays photon is
(Bwp 2018, Grw 2010)
(A) 9.1×10^{-31} kg (B) 1.67×10^{-27} kg (C) zero (D) smaller than a light ray photon
(Mtn GI 2018)
- X-rays are similar in nature to:
(A) γ -rays (B) β -rays (C) α -rays (D) Cathode rays
- Bremsstrahlung radiations are example of:
(Rwp 2018)
(A) Atomic spectra (B) Molecular spectra (C) Continuous spectra (D) Discrete spectra
- K_{α} -X rays are produced due to transition of electrons from:
(Lhr 2016 Group II)
(A) K to L shell (B) L to K shell (C) M to K shell (D) M to L shell

ANSWER KEY'S

- | | | | | | | | | | | | | | | | | | | | |
|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|-----|---|
| 1. | C | 2. | C | 3. | A | 4. | D | 5. | D | 6. | B | 7. | C | 8. | A | 9. | C | 10. | B |
|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|-----|---|

Q.10 How does uncertainty principle explain that electrons cannot exist inside the nucleus?

Ans.

UNCERTAINTY WITHIN THE ATOM

Due to dual nature of matter there is limitation in the accuracy of simultaneous measurement of the position and momentum of a particle.

According to Heisenberg,

"The product of uncertainty in position and momentum is of the order of plank's constant"

$$\text{i.e. } \Delta P \Delta x \geq \frac{h}{2\pi}$$

$$\text{or } \Delta P \Delta x \approx h$$

The uncertainty is more significant within the atom.



Does electron reside inside nucleus?

According to uncertainty principle, electron cannot exist inside the nucleus.

The size of the nucleus is less than 10^{-14} m in radius. Thus for an electron to be confined within the nucleus, the uncertainty in the position will be of the order of 10^{-14} . So $\Delta x = 10^{-14}$ m and uncertainty in the momentum is ΔP , then

$$\Delta P \geq \frac{h}{\Delta x}$$

$$\Delta P \geq \frac{6.63 \times 10^{-34}}{10^{-14}}$$

$$\Delta P = 6.63 \times 10^{-20} \text{ kgms}^{-1}$$

As

$$m\Delta v = 6.63 \times 10^{-20} \text{ kgms}^{-1}$$

$$[\Delta P = m\Delta v]$$

$$\Delta v = \frac{6.63 \times 10^{-20}}{9.11 \times 10^{-31}}$$

$$\Delta v \geq 7.3 \times 10^{10} \text{ m / sec}$$

Result

Thus if the electron is to be confined to the nucleus, its speed would be greater than the speed of light (3×10^8 m/s), which is not possible. So the electron can not reside inside the nucleus.

Does electron reside inside the atom?

Now to check whether it reside inside the atom, we consider a hydrogen atom whose radius is about 5×10^{-11} m.

Again applying Heisenberg's Principle

$$\Delta x \Delta p \approx h$$

or
$$\Delta p = \frac{h}{\Delta x}$$

As
$$\Delta p = m\Delta v$$

Therefore
$$m\Delta v = \frac{h}{\Delta x}$$

Or
$$\Delta v = \frac{h}{m\Delta x}$$

Putting value, we get

$$\Delta v = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 5 \times 10^{-11}}$$

$$\Delta v = 1.46 \times 10^7 \text{ ms}^{-1}$$

Result:

As the speed of the electron is less than the speed of light. So the electron exists inside an atom but outside the nucleus.

Q.11 What is laser? Describe its principle and operation.

GRW 2017, FSD 2017, D.G.KHAN 2016

Ans.

LASER

Laser is an acronym for **light Amplification by Stimulated Emission of Radiation**. Laser are used for producing an intense, monochromatic and unidirectional coherent beam of light."



Working

The working of laser involve two most important terms

- (a) Stimulated emission
- (b) Population inversion

SPONTANEOUS AND STIMULATED EMISSION

Consider a sample of free atoms, some of which are in ground state with energy E_1 and some in the excited state E_2 as shown in figure. The photons of energy $hf = E_2 - E_1$ are incident on this sample.

The incident photon is absorbed by an atom in the ground state E_1 and the atom is excited to state E_2 . This process is called stimulated or **induced absorption** as shown in Fig. (a). Once the atom is excited, then two things can happen to an atom,

i) Spontaneous Emission

The excited atom may decay by spontaneous emission by emitting a photon of energy $hf = E_2 - E_1$ in any arbitrary direction as shown in Fig. (b)

ii) Stimulated Emission

The excited atom decays by stimulated or induced emission. In this case, the photon of energy $hf = E_2 - E_1$ induces the atom to decay by emitting a photon of same energy, going in the same directions, as shown in Fig. (c)

Thus, we obtain an intense, unidirectional beam, by stimulated emission. For proper working there would be more stimulated emission than spontaneous emission.

POPULATION INVERSION AND LASER ACTION

Let us consider a simple case of material whose atoms can reside in three different states as shown in figure. E_1 is the ground energy state. E_3 is the excited state in which the atom can reside only for 10^{-8} sec and E_2 is called metastable state in which the atom can reside for 10^{-3} sec.

A metastable state is an excited state in which an excited electron is unusually more stable and from which the electron spontaneously fall to lower state after relatively longer time.

The transition to the metastable state are difficult as compared to other excited states. So instead of direct excitation to this state, the electrons are excited to higher level for spontaneous fall to metastable state.

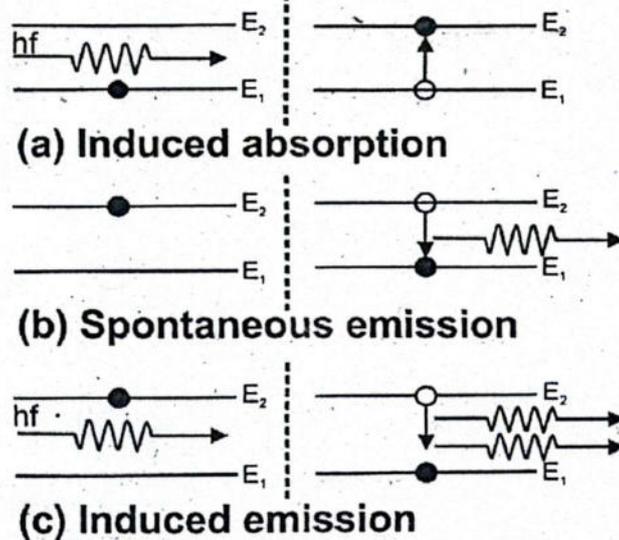
Population Inversion

Let the incident photons of energy $hf = E_3 - E_1$ raised the atom to excited state E_3 from ground state E_1 . The excited atoms do not decay back to E_1 but the atom decay to E_2 spontaneously. The atom reaches state E_2 much faster than they leave state E_2 .

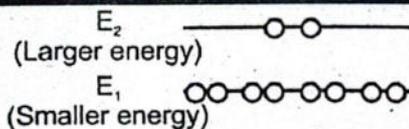
In this situation, the state E_2 contains more atom than E_1 . This situation is called population inversion.

Stimulated Emission

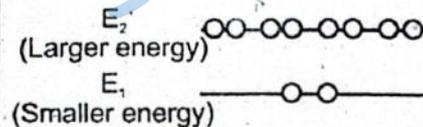
The atom in metastable state E_2 are bombarded by a photons of energy $hf = E_2 - E_1$. This results into induced or stimulated emission, giving an intense, coherent mono-chromatic beam of light in the direction of the incident photons.



For Your Information

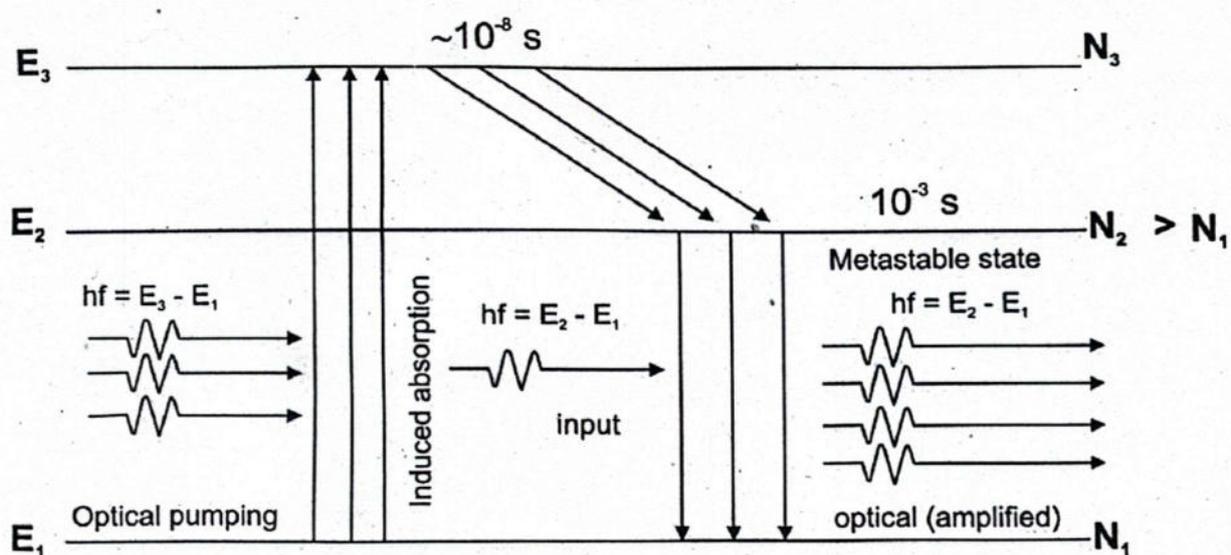


A normal population of atomic energy state, with more atomic in the lower energy state E_1 , than in the excited state E_2 .



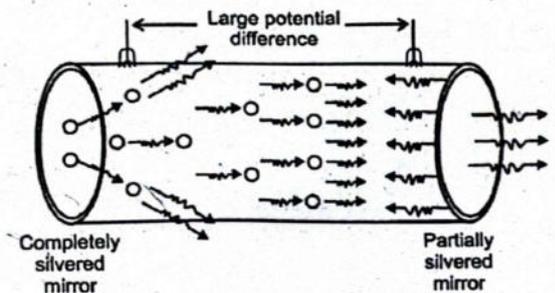
A population inversion, in which the higher energy state, has a greater population than the lower energy state.





The emitted photons must be confined in the assembly long enough to stimulate further emission from other excited atoms. This is achieved by using mirror at the two ends of the assembly. One end is made totally reflecting and the other end is partially transparent to allow the laser beam to escape as shown in figure.

As the photon move back and forth between the reflecting mirrors, they continue to stimulate other excited atoms to emit the photons. As the process continues the number of photons multiply, and the resulting radiation is, therefore, much more intense and coherent than light from ordinary source.



Q.12 What is the Helium-Neon Laser? Explain.

Rwp 2015, Lhr 2016, Grw 2014 FSD 2014, Mtn 17

Ans. HELIUM-NEON LASER

It is most common type of laser used in physics laboratories. It consists of a discharge tube filled with 15% neon gas and 85% helium gas. The neon is the lasing or active medium in this tube. Helium and neon have nearly identical metastable states. Helium is located at the level of 20.61 eV and neon at 20.66 eV.

Working

Pumping

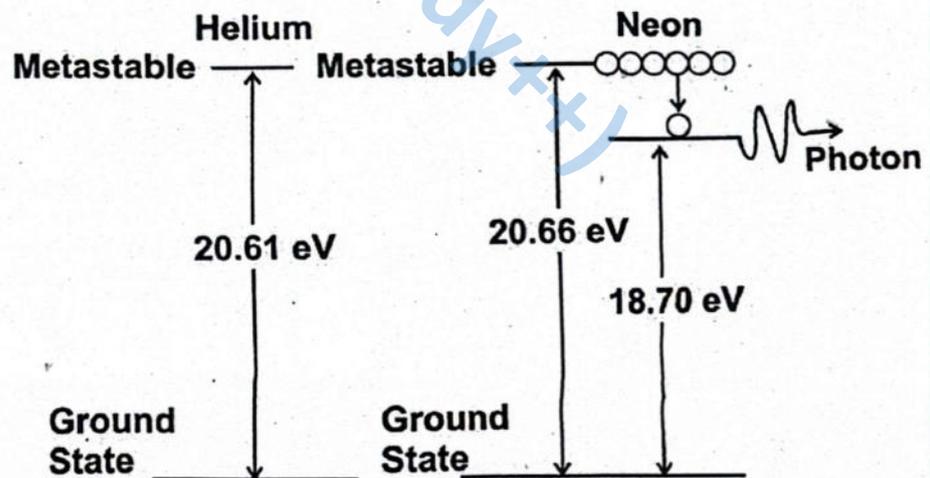
The high voltage electric discharge excites the electrons in some of helium atoms to 20.61eV state.

Population inversion

In this laser population inversion in the neon is achieved by direct collision with same energy electrons of helium atoms.

Thus excited helium atoms collide with neon atoms, each atom transfers its own 20.61 eV of energy to an electron in the neon atom along with 0.05 eV of K.E, from the moving atom. As a result the electrons in neon atom are raised to 20.66 eV state.

In this way population inversion is sustained in the neon gas relative to the energy level of 18.70 eV.



Stimulated emission(Laser Action)

Spontaneous emission from neon atoms start laser action and stimulated emission causes electrons in the neon to drop from 20.66 eV to 18.70 eV level and red laser light of the wavelength 632.8 nm corresponding to 1.96 eV energy is produced.

Q.14 What are the Uses of Laser in medicine and industry?

Ans.

USES OF LASER

1) Surgical Tool

Laser beams are used as a surgical tool for welding detached retinas.

2) Destroy Tissue

The narrow intense beam of laser can be used to destroy the tissue in a particular area. Tiny organelles with the living cell have been destroyed by using laser to study how the absence of that organelle affects the behaviour of cell.

3) To diagnose Diseases

The helium-neon-beam of laser is used to diagnose the disease of eye.

4) Cancer Cure

Fine focused beam has been used to destroy cancerous and pre-cancerous cell.

5) Seal off the Capillaries

The heat of the laser seals off capillaries and lymph vessels to prevent the spread of disease.

6) Welding and Drilling

The intense heat produced in small area by laser may used for welding and drilling the tiny holes in hard materials.

7) Lining up the Equipment

The precise straightness of laser beam is also useful to surveyor for lining up equipment.

8) Fusion Reactions

It is potential energy source for inducing fusion reaction.

9) Telecommunication

It can be use for telecommunication in fiber optical.

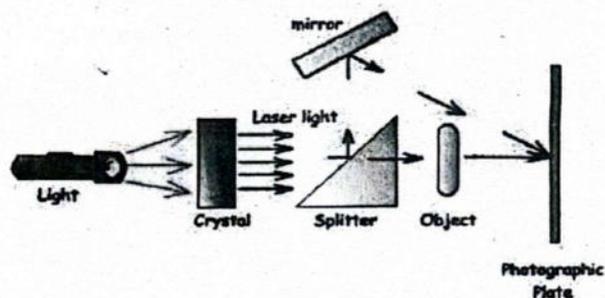
10) Holography(Whole picture)

Laser beam can used to generate the three dimensional image of objects in a process called holography.

To Read Bar Codes

He-Ne laser is the laser whose narrow red beam is used in super markets to read bar codes.

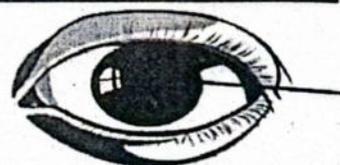
Holography



Holography

It is a scheme for recording the intensity and phase of the waves from objects. This type of image formation called holography from Greek word meaning entire picture and the image is called hologram.

Do You Know?



The helium-neon laser beam is being used to diagnose diseases of the eye. The use of laser technology in the field of ophthalmology is widespread.

MCQ's From Past Board Papers

- Atom can reside in metastable state for:
(A) 10^{-1} sec (B) 10^{-2} sec (C) 10^{-3} sec (D) 10^{-4} sec
(Lhr, Swl, Fsd 2014, Sgd 2016 G-II, D.G.Khan, Mtn 2015 G – II)
- In Helium-Neon laser, discharge tube is filled with Neon gas:
(A) 10% (B) 15% (C) 85% (D) 90%
(Swl 2016, Lhr 2015 G – II)
- For holography we use a beam of:
(A) γ -rays (B) X-rays (C) β -rays (D) LASER
(D.G.Khan 2017, Lhr 2011, 12 G I)



4.	Laser is beam of light which is:	(A) monochromatic	(B) coherent	(C) unidirectional	(D) All these	(Rwp 2014)
5.	What is the colour of light emitted from He-Ne Laser?	(A) Blue	(B) Green	(C) Red	(D) Yellow	(Grw 2011)
6.	If number of atoms in metastable state (E_2) is " N_2 " and in ground state (E_1) is " N_1 " the population inversion means ____.					(Fed 2014)
		(A) $N_2 = N_1$	(B) $N_2 < N_1$	(C) $N_2 > N_1$	(D) $\frac{N_1}{N_2} = \frac{E_2}{E_1}$	
7.	Which is not characteristic of LASER?					(Fsd 2016)
		(A) Monochromatic	(B) Coherent	(C) Intense	(D) Multi directional	
8.	Normally electron can reside in excited state for about					(Bwp 2017 G II)
		(A) 10^{-3} s	(B) 10^{-8} s	(C) 10^{-6} s	(D) 10^8 s	
9.	The meta-stable state is _____ than normal excited state.					(D.G.Khan GI 2018)
		(A) 10^{-5} times larger	(B) 10^{-8} times smaller	(C) 10^5 times larger	(D) 10^{-3} times larger	
10.	Metastable state of Neon is:					(Sgd GII 2018)
		(A) 20.66 eV	(B) 20.61 eV	(C) 18.70 eV	(D) 1.60 eV	

ANSWER KEY'S

1.	C	2.	B	3.	D	4.	D	5.	C	6.	C	7.	D	8.	B	9.	C	10.	A
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IMPORTANT SHORT QUESTIONS FOR BOARD EXAMS

1. What is meant by CAT-Scanner? (Lhr 2016 Group II)

Ans. CAT SCANNER

It is basically, consists of X-rays source with several hundred oppositely adjusted detectors. Each detector measures absorption of X-rays along a thin line through the subject. The entire system is linked through a computer that is why it is named as computerized axial tomography (CAT) and is widely used as a source of medical diagnostic.

2. What is biological effects of X-rays? (Lhr 2016 Group II)

Ans. Biological Effects of X-rays

X-ray are ionizing radiations. They may cause damage to living tissue. As X-rays photons are absorbed in tissues, they break molecular bonds and create highly reactive free radicals (such as H and OH) which in turn can disturb the molecular structure of proteins and especially the genetic material. Young and rapidly growing cells are sensitive, hence X-rays are useful for selective destruction of cancer cells. The X-ray can cause cancer by excessive use. Even when the organism itself shows no apparent damage, excessive use may cause the changes in reproductive system that will affect the organism's offspring.

3. Write down the two uses of LASER. (Grw 2016)

Ans. Uses of LASER

- Laser beams are used as a surgical tool for welding detached retinas.
- Fine focused beam of laser has been used to destroy cancerous and pre-cancerous cell.
- The precise straightness of laser beam is also useful to surveyor for lining up equipment.
- It is potential energy source for inducing fusion reaction.
- It can be use for telecommunication in fibre optical.

4. Define (a) Population inversion (b) Metastable state (Sgd 2016 Group I) (Rwp 2016)

Ans. Metastable state: A metastable state is an excited state in which an excited electron is unusually more stable and from which the electrons come to lower state after relatively longer time.

It plays important role in the operation of laser because phase coherence can be obtained by this way.

Population inversion: It is the state of an atom, when there are more number of excited electrons in the higher energy state than the lower energy state.



5. Bohr's theory of hydrogen atom is based on several assumptions. Do any of these assumptions contradict classical physics? (Sgd 2015 Group II)

Ans. Yes, the *first postulate* of Bohr's theory of hydrogen atom contradicts classical physics.

Explanation

According to classical physics, accelerating charge (either oscillating or revolving) radiates electromagnetic waves. So energy of orbiting electron decreases continuously, its orbit become smaller and smaller and it should fall into the nucleus but according to Bohr's theory, an electron can move around the nucleus in certain circular orbits without radiating.

6. Define Continuous Spectra and Line Spectra. (Bwp 2015)

Ans. Continuous Spectrum:

A radiation spectrum in which the frequencies of the radiations emitted by the atoms of a substance are so close to each other that they give continuous row of overlapping images is called a continuous spectrum.

Example

Black body radiation spectrum is the example of continuous spectra.

Line or discrete spectrum:

A spectrum consisting of discrete lines corresponding to single wavelengths of emitted radiation is called as line spectrum.

Example

Atomic spectra are examples of discrete or line spectra.

7. What are the advantages of laser over ordinary light? (Mtn 2015 G II) (Grw 2015) (Lhr 2015 G II) (Lhr 2016 G I) (D.G.Khan 2015 G I) (D.G.Khan 2015 G II) (Swl 2015)

Ans. Advantages of LASER over ordinary light

- | | |
|---|----------------------------------|
| (i) It is <u>intense</u> beam of light | (ii) It is <u>mono chromatic</u> |
| (iii) It is <u>unidirectional</u> | (iv) It is <u>coherent</u> |
| (v) It can be <u>sharply focused</u> to a very fine spot. | |

8. What is difference between excitation and ionization energy?

Ans. Difference Between Excitation And Ionization Energies

The energy required to lift an electron from ground state to any higher allowed state is called excitation energy and corresponding potential is called excitation potential.

The energy required to completely remove an electron from the atom is called ionization energy and corresponding potential is called ionization potential.

The ionization energy of Hydrogen atom ground energy state is -13.6 eV .

9. What is the difference between spontaneous and stimulated emission?

Ans. Spontaneous emission:

As excited is highly instable state with life time of 10sec, so the electron will de excite itself with emission of photon.in any arbitrary direction is called spontaneous emission.

Stimulated emission:

If atom sat in excited (metastable) for a longer life time of about 10^{-3} sec then an incident photon of ener equal to energy to difference of two energy levels. induces the atom to decay by emitting a photon that travel in the direction of incident photon. This process is called stimulated or induced emission.



FORMULAE

1	Balmer series	$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$ where $n=3,4,5,\dots$	
2	Lyman series	$\frac{1}{\lambda} = R_H \left(\frac{1}{1^2} - \frac{1}{n^2} \right)$ where $n = 2, 3, 4, \dots$	
3	Paschen series	$\frac{1}{\lambda} = R_H \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$ where $n = 4, 5, 6, \dots$	
4	Brackett series	$\frac{1}{\lambda} = R_H \left(\frac{1}{4^2} - \frac{1}{n^2} \right)$ where $n = 5, 6, 7, \dots$	
5	Pfund series	$\frac{1}{\lambda} = R_H \left(\frac{1}{5^2} - \frac{1}{n^2} \right)$ where $n = 6, 7, 8, \dots$	
6	General formula for any spectral series	$\frac{1}{\lambda} = R_H \left(\frac{1}{p^2} - \frac{1}{n^2} \right) \quad n > p$ Where $n = p + 1, p + 2, p + 3, \dots$	
7	Angular momentum of electron in H-atom	$mvr = \frac{nh}{2\pi}$	
8	Energy of emitted photon	$hf = E_n - E_p$	
9	Velocity of electron in H-atom	$v_n = \frac{nh}{2\pi m r_n}$	$v_n = \frac{2\pi k e^2}{nh}$
10	Radius of nth orbit in H-atom	$r_n = \frac{n^2 h^2}{4\pi^2 k e^2 m}$	$r_n = n^2 \times 0.053 \text{ nm}$ $r_n = r_1 n^2$
11	K.E. of electron in nth orbit of H-atom	$\text{K.E.} = \frac{1}{2} m v_n^2$	$\text{K.E.} = \frac{ke^2}{2r_n}$
12	P.E. of electron in nth orbit of H-atom	$U = -q\Delta V$	$U = -\frac{ke^2}{r_n}$
13	T.E. of electron in nth orbit of H-atom	$E_n = -\left(\frac{2\pi^2 k^2 m e^4}{h^2} \right) \frac{1}{n^2}$	$E_n = -\frac{E_0}{n^2}$ $E_n = -\frac{13.6}{n^2} \text{ eV}$
14	Emission spectrum of Hydrogen atom	$\frac{1}{\lambda} = \frac{E_0}{hc} \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$	$\frac{1}{\lambda} = R_H \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$
15	K_α - characteristic X- rays	$hf_{K\alpha} = E_L - E_K$	

16	K_{β} - characteristic X-rays	$hf_{k\beta} = E_M - E_K$	
17	Maximum energy of breaking radiation	$K.E = hf_{\max} = \frac{hc}{\lambda_{\min}}$	$K.E = hf_{\max} = \frac{hc}{\lambda_{\min}}$
18	Minimum wavelength of breaking radiation	$\lambda_{\min} = \frac{hc}{K.E}$	$\lambda_{\min} = \frac{hc}{Ve}$

UNITS

1	Rydberg's constant	m^{-1}	
2	Planck's constant	J-s	
3	Energy of electron in an orbit	J	eV
4	Speed of light	m/s	
5	Angular momentum	J-s	

CONSTANTS

1	Rydberg constant	$1.097 \times 10^7 m^{-1}$	
2	Planck's constant	$6.63 \times 10^{-34} J-s$	
3	Speed of light	$3 \times 10^8 m/s$	

SOLVED EXAMPLES

Example 20.1:

Find the speed of the electron in the first Bohr orbit.

Given data:

First Bohr orbit (i.e. Ground state) = $n = 1$

To find:

Speed of electron = $v = ?$

Calculations:

Using the relation

$$v_n = \frac{2\pi ke^2}{nh}$$

As electron lies in the first orbit i.e., $n = 1$, thus

$$v_1 = \frac{2\pi ke^2}{h} \quad \dots\dots(1)$$

where k = Coulomb's constant = $9 \times 10^9 Nm^2C^{-2}$

e = Charge on electron = $1.6 \times 10^{-19} C$



$$h = \text{Plank's constant} = 6.63 \times 10^{-34} \text{ Js}$$

Putting all the values in equation (1), we get

$$v_1 = \frac{2 \times 3.14 \times 9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.63 \times 10^{-34}}$$

$$v_1 = \frac{2 \times 3.14 \times 9 \times 10^9 \times 2.56 \times 10^{-38}}{6.63 \times 10^{-34}}$$

$$v_1 = \frac{144.69 \times 10^{-29}}{6.63 \times 10^{-34}}$$

or

$$v_1 = 2.18 \times 10^6 \text{ ms}^{-1}$$

SHORT QUESTIONS OF THE EXERCISE

Write the short answer to the following questions:

20.1 Bohr's theory of hydrogen atom is based upon several assumptions. Do any of these assumptions contradict classical physics? (Grw 2008,10,11, Lhr 2009)

Ans. Yes, the *first postulate* of Bohr's theory of hydrogen atom contradicts classical physics.

Explanation

According to classical physics, accelerating charge (either oscillating or revolving) radiates electromagnetic waves. So energy of orbiting electron decreases continuously, its orbit become smaller and smaller and it should fall into the nucleus but according to Bohr's theory, an electron can move around the nucleus in certain circular orbits without radiating.

20.2 What is meant by a line spectrum? Explain, how line spectrum can be used for the identification of elements? (Rwp 2015, Grw 2015, Bwp 2011, DG Khan 2017, 18)

Ans. Line Spectrum

When a gas much low pressure is excited by passing an electric current (discharge) through it, the spectrum of emitted radiation is in the form of discrete sharp parallel lines. This type of spectrum is called line spectrum.

Identification of elements

In line spectrum, each line corresponds to a definite wavelength and frequency. Each element has its own set of wavelengths in the line spectrum, because electrons of atom in different elements have different energy in their orbits.

20.3 Can the electron in the ground state of hydrogen absorb a photon of energy 13.6 eV and greater than 13.6 eV (Sgd 2018 G II, Lhr 2016, Bwp 2011, Grw 2018)

Ans. Yes, an electron in the ground state of hydrogen atom can absorb a photon of energy 13.6 eV and greater than 13.6 eV.

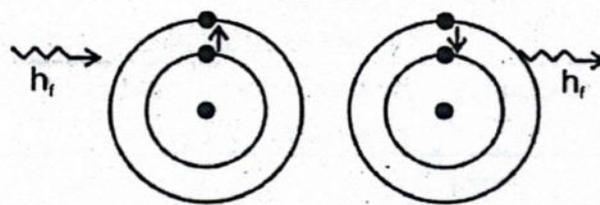
Reason

Ionization energy of hydrogen atom in ground state is 13.6eV. So if hydrogen absorbs a photon of energy greater 13.6 eV then the surplus energy of photon appears as kinetic energy of electron.



20.4 How can the spectrum of hydrogen contain so many line when hydrogen contains on electron?
(Grw 2017, Lhr 2018, Bwp2016, DG khan 2018, Mirpur 2017)

Ans. When hydrogen atom is excited, its electron in ground state jumps up to some higher energy state. Now, when it de-excites, electron does not come to ground state directly but jumps to lower energy in multiple steps and every jump corresponds is a certain wavelength.



20.5 Is energy conserved when an atom emits a photon of light?
(Rwp 2014, Grw 2009, 2011)

Ans. Yes, energy is conserved when an atom emits a photon of light.

Reason

When an electron jumps from lower energy state to a higher energy state it absorbs a photon of energy and when it de-excites, it emits a photon of same energy. So energy is conserved.

20.6 Explain why a glowing gas gives only certain wavelengths of light and why that gas is capable of absorbing the same wavelengths? Give a reason why it is transparent to other wavelength?

Ans. **Reason for emitting certain wavelengths**

When an electron jumps higher energy state to lower energy state it emits a photon whose energy is equal to the difference of (energies of) two levels.

As energy levels are discrete so only certain wavelengths are emitted.

Reason for absorbing the same λ

When an electron jumps from lower energy state to a higher energy state it absorbs a photon whose energy is equal to the energy difference between the two levels.

Why it is transparent to other wavelength

An atom absorbs only those photons whose energy is equal to energy difference between any two levels. Therefore, it is transparent to other photons (wavelengths)

20.7 What do we mean when we say that the atom is excited?
(Grw 2011, Bwp 2008,09, DG.khan 2009,Fsd 2011)

Ans. **Excited atom**

When an electron jumps from lower energy level to a higher energy level by absorbing a photon whose energy is equal to energy difference between the two states, the atom is said to be in excited state.

20.8 Can x-rays be reflected, refracted, diffracted and polarized just like any other waves? Explain.
(Sgd 2017 G II, Fsd 2015, Sgd 2013, Grw 2010, 15)

Ans. Yes, x-rays can be reflected, diffracted and polarised.

Explanation

This is because that x-rays are electromagnetic waves. As the wave length of x-rays is much shorter than that of ordinary light waves. So, the circumstances for these phenomena may be different. For example, x-rays can diffracted by crystals only.

20.9 What are the advantages of lasers over ordinary light?
(Grw 2008, Lhr 2009,11, Rwp 2016)

Ans. **Advantages of LASER over ordinary light**

(i). It is intense beam of light



- (ii) It is mono chromatic
- (iii) It is unidirectional
- (iv) It is coherent
- (v) It can be sharply focused to a very fine spot.

20.10 Explain why Laser action could not occur without population inversion between atomic levels?

(Lhr 2016, Bwp 2009, Fsd 2011)

Ans. Reason

If number of atoms in metastable state is not greater than those in ground state, the incident photons will be absorbed by atoms in the ground state, these atoms are excited to metastable state.

In this case, LASER amplification could not occur.

Hence, the rate of induced absorption will be greater than the rate of stimulated emission.



Exercise Problems

20.1 A hydrogen atom is in its ground state ($n = 1$). Using Bohr's theory, calculate (a) the radius of the orbit, (b) the linear momentum of the electron, (c) the angular momentum of the electron (d) the kinetic energy, (e) the potential energy, and (f) the total energy.

Given data:

A hydrogen atom in the ground state i.e., $n = 1$

Charge on electron = $e = 1.6 \times 10^{-19} \text{C}$

To find:

- (a) Radius of the orbit = $r_1 = ?$
- (b) Linear momentum of electron = $p_1 = ?$
- (c) Angular momentum of electron = $L = ?$
- (d) Kinetic energy = K.E. = ?
- (e) Potential energy = P.E. = ?
- (f) Total energy = T.E. = ?

Calculations:

(a) As for Bohr orbit radius of the hydrogen atom is

$$r_n = \frac{n^2 h^2}{4\pi^2 k m e^2}$$

For ground state $n = 1$

$$\text{Thus } r_n = \frac{h^2}{4\pi^2 k m e^2} \quad \dots\dots(1)$$

Where $h = 6.63 \times 10^{-34} \text{Js}$



$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

$$m = 9.1 \times 10^{-31} \text{ kg}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

Putting the values in equ. (1), we get

$$r_1 = \frac{(6.63 \times 10^{-34})^2}{4 \times (3.14)^2 \times 9 \times 10^9 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$$r_1 = \frac{43.956 \times 10^{-68}}{4 \times 9.859 \times 9 \times 10^9 \times 9.1 \times 10^{-31} \times 2.56 \times 10^{-38}}$$

$$r_1 = \frac{43.956 \times 10^{-68}}{8268.81 \times 10^{-60}}$$

$$r_1 = 0.0053 \times 10^{-8}$$

$$r_1 = 0.53 \times 10^{-10} \text{ m}$$

(b) Linear momentum of the electron = $p_1 = ?$

As speed of electron in nth orbit is given by $v_n = \frac{2\pi ke^2}{nh}$

But for ground state $n = 1$, so

$$v_n = \frac{2\pi ke^2}{nh}$$

$$v_1 = \frac{2 \times 3.14 \times 9 \times 10^9 \times (1.6 \times 10^{-19})^2}{(1)(6.63 \times 10^{-34})}$$

$$v_1 = \frac{2 \times 3.14 \times 9 \times 10^9 \times 2.56 \times 10^{-38}}{6.63 \times 10^{-34}}$$

$$v_1 = 2.18 \times 10^6 \text{ m/sec}$$

Expression for linear momentum is given by

$$p_1 = mv_1 \quad \dots\dots(2)$$

Substituting values of m and v_1 in eq. (2)

$$p_1 = 9.1 \times 10^{-31} \times 2.18 \times 10^6$$

$$p_1 = 19.838 \times 10^{-25}$$

$$p_1 = 1.99 \times 10^{-24} \text{ kg m/sec}$$

(c) Orbital angular momentum of the electron = $L = ?$

As orbital angular momentum can be expressed as

$$L_n = m v_n r_n$$

But for ground state $n = 1$

or $L_1 = m v_1 r_1$

Putting the values, we get

$$L_1 = (9.11 \times 10^{-31})(2.18 \times 10^6)(0.053 \times 10^{-9})$$

$$L_1 = 1.05 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}$$



(d) Kinetic energy = K.E. = ?

$$(K.E.)_n = \frac{1}{2}mv_1^2$$

For ground state = $n = 1$

$$(K.E.)_1 = \frac{1}{2}m v_1^2 \quad \text{----- (3)}$$

Putting the values in equ. (3), we get

$$(K.E.)_1 = \frac{1}{2} \times 9.11 \times 10^{-31} \times (2.18 \times 10^{-6})^2$$

$$(K.E.)_1 = \frac{1}{2} (9.11 \times 10^{-31}) (4.78 \times 10^{-12})$$

$$(K.E.)_1 = 21.69 \times 10^{-19} \text{ J}$$

or $(K.E.)_1 = \frac{21.69 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$

$$\boxed{(K.E.)_1 = 13.6 \text{ eV}}$$

(e) Potential energy = P.E. = ?

Potential energy is given by the relation

$$P.E. = -\frac{ke^2}{r_n}$$

For ground state = $n = 1$

$$P.E. = -\frac{ke^2}{r_1}$$

Putting the values, we get

$$P.E. = -\frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{0.53 \times 10^{-10}}$$

$$P.E. = -\frac{9 \times 10^9 \times 2.56 \times 10^{-38}}{0.53 \times 10^{-10}}$$

$$P.E. = -4.35 \times 10^{-18} \text{ J}$$

$$P.E. = -\frac{4.35 \times 10^{-18}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{P.E. = -27.2 \text{ eV}}$$

(f) Total energy = T.E. = ?

$$\text{Total energy} = K.E. + P.E. \quad \text{----- (4)}$$

Putting the values of K.E and P.E in equ. (4), we get

$$\text{Total energy} = (13.6 \text{ eV} - 27.2 \text{ eV})$$

$$\boxed{\text{Total energy} = -13.6 \text{ eV}}$$

20.2 What are the energies in eV of quanta of wavelength? $\lambda = 400, 500$ and 700 nm .

Given data:

$$\lambda_1 = 400 \text{ nm} = 400 \times 10^{-9} \text{ m}$$

$$\lambda_2 = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$$

$$\lambda_3 = 700 \text{ nm} = 700 \times 10^{-9} \text{ m}$$



To find:

Energy $E_1 = ?$, $E_2 = ?$, $E_3 = ?$

Calculations:

As energy of photon is given by

$$E = hf$$

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

(i) Calculation of E_1

$$E_1 = \frac{hc}{\lambda_1}$$

Putting the values, we get

$$E_1 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9}}$$

$$E_1 = \frac{19.89 \times 10^{-26}}{400 \times 10^{-9}} = 4.97 \times 10^{-19} \text{ J}$$

$$E_1 = \frac{4.97 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{E_1 = 3.10 \text{ eV}}$$

(ii) Calculation of E_2

$$E_2 = \frac{hc}{\lambda_2}$$

Putting the values, we get

$$E_2 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{500 \times 10^{-9}}$$

$$E_2 = \frac{19.89 \times 10^{-26}}{5 \times 10^{-9}} = 3.98 \times 10^{-19} \text{ J}$$

$$E_2 = \frac{3.98 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{E_2 = 2.49 \text{ eV}}$$

(iii) Calculation of E_3

$$E_3 = \frac{hc}{\lambda_3}$$

Putting the values, we get

$$E_3 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{700 \times 10^{-9}}$$

$$E_3 = \frac{19.89 \times 10^{-26}}{7 \times 10^{-9}} = 2.84 \times 10^{-19} \text{ J}$$

$$E_3 = \frac{2.84 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{E_3 = 1.77 \text{ eV}}$$



20.3 An electron jumps from a level $E_i = -3.5 \times 10^{-19}$ J to $E_f = -1.20 \times 10^{-18}$ J. What is the wavelength of the emitted light?

Given data:

Energy of electron in ground state $E_i = -3.5 \times 10^{-19}$ J

Energy of electron in excited state $E_f = -1.20 \times 10^{-18}$ J

To find:

Wavelength of emitted light = $\lambda = ?$

Calculations:

According to third postulate of Bohr atomic model

$$hf = E_i - E_f$$

$$\text{or } \frac{hc}{\lambda} = E_i - E_f$$

$$\text{or } \lambda = \frac{hc}{E_f - E_i}$$

Putting the values, we get

$$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{-1.20 \times 10^{-18} - (-3.5 \times 10^{-19})}$$

$$\lambda = \frac{19.89 \times 10^{-26}}{-1.20 \times 10^{-18} + 0.35 \times 10^{-18}}$$

$$\lambda = \frac{19.89 \times 10^{-26}}{0.85 \times 10^{-18}}$$

$$\lambda = 23.4 \times 10^{-9} \text{ m} = 234 \times 10^{-9} \text{ m}$$

$$\lambda = 234 \text{ nm}$$

20.4 Find the wavelength of the spectral line corresponding to the transition in hydrogen from $n = 6$ state to $n = 3$ state?

Given data:

State of n th orbit = $n = 6$

State of p th orbit = $p = 3$

To find:

Wavelength = $\lambda = ?$

Calculations:

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

Where R_H is Rydberg constant and $R_H = 1.0974 \times 10^7 \text{ m}^{-1}$

Putting the values, we get

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{6^2} \right)$$

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{9} - \frac{1}{36} \right)$$



$$\frac{1}{\lambda} = 1.0974 \times 10^7 \times \frac{3}{36}$$

$$\frac{1}{\lambda} = \frac{1.0974 \times 10^7}{12}$$

or $\lambda = \frac{12}{1.0974 \times 10^7}$

$$\lambda = 1093 \times 10^{-6} \text{ m}$$

$$\boxed{\lambda = 1093 \text{ nm}}$$

20.5 Compute the shortest wavelength radiation in the Balmer series? What value of n must be used?

Given data:

Balmer series is given

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

To find:

Shortest wavelength for Balmer Series = $\lambda = ?$

Calculations:

As Balmer series is given by

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

For shortest wavelength frequency of photon is maximum and that is possible when n approaches to infinity (i.e., $n = \infty$)

Putting the values in equ. (1), we get

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{\infty^2} \right) \quad \left(\because \frac{1}{\infty} = 0 \right)$$

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{4} - 0 \right)$$

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \times \frac{1}{4}$$

or $\lambda = \frac{4}{1.0974 \times 10^7} = 3.645 \times 10^{-7} \text{ m}$

$$\lambda = 364.5 \times 10^{-9} \text{ m}$$

$$\boxed{\lambda = 364.5 \text{ nm}}$$

The value of n used is infinity (i.e.).

$$\boxed{n = \infty}$$

20.6 Calculate the longest wavelength of radiation for the Paschen series.

Given data:

Paschen series is given by

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



To find:

Longest wavelength for Paschen series = $\lambda = ?$

Calculations:

For Paschen series

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

For longest wavelength, frequency of photon is shortest and that is possible for paschen series when $n = 4$

Putting the values, we get

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

$$\frac{1}{\lambda} = 1.0974 \times 10^7 \left(\frac{1}{9} - \frac{1}{16} \right) = 1.0974 \times 10^7 \times \frac{7}{144}$$

$$\lambda = \frac{144}{1.0974 \times 10^7 \times 7} = 18.75 \times 10^{-7} \text{ m}$$

$$\lambda = 1875 \times 10^{-9} \text{ m}$$

$$\lambda = 1875 \text{ nm}$$

20.7 Electrons in an X-ray tube are accelerated through a potential difference of 3000V. If these electrons were slowed down in a target, what will be the minimum wavelength of X-rays produced?

Given data:

Potential difference = $V = 3000$ volts

To find:

Minimum wavelength of x-rays = $\lambda_{\min} = ?$

Calculations:

As K.E. = hf_{\max}

But K.E. = Ve

Thus $Ve = hf_{\max}$

Minimum wavelength corresponds to maximum frequency.

$$\text{or } Ve = \frac{hc}{\lambda_{\min}}$$

$$\text{or } \lambda_{\min} = \frac{hc}{Ve}$$

Putting the values, we get

$$\lambda_{\min} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3000 \times 1.6 \times 10^{-19}} = \frac{19.89 \times 10^{-26}}{4800 \times 10^{-19}}$$

$$\lambda_{\min} = 0.00414 \times 10^{-7} \text{ m}$$

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

20.8 The wavelength of K X-ray from copper is 1.377×10^{-10} m. What is the energy difference between the two levels from which this transition results?

Given data:

Wavelength of x-rays = $\lambda = 1.377 \times 10^{-10}$ m

To find:

Energy difference = $\Delta E = ?$



Calculations:

$$\text{As } \Delta E = hf$$

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

$$\left(\because f = \frac{c}{\lambda} \right)$$

Putting the values, we get

$$\Delta E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.377 \times 10^{-10}}$$

$$\Delta E = \frac{19.89 \times 10^{-26}}{1.377 \times 10^{-10}}$$

$$\Delta E = 14.44 \times 10^{-16} \text{ Joules}$$

$$\Delta E = \frac{14.44 \times 10^{-16}}{1.6 \times 10^{-14}} \text{ eV}$$

$$\Delta E = 9.025 \times 10^3 \text{ eV}$$

$$\text{or } \boxed{\Delta E = 9.03 \text{ keV}}$$

20.9 A tungsten target is struck by electrons that have been accelerated from rest through 40 kV potential differences. Find the shortest wavelength of the bremsstrahlung radiation emitted?

Given data:

$$\text{Potential difference} = V = 40 \text{ kV} = 40 \times 10^3 \text{ volt}$$

To find:

$$\text{Shortest wavelength} = \lambda_{\min} = ?$$

Calculations:

$$\text{As } \text{K.E.} = hf_{\max} \quad (\text{As K.E.} = Ve)$$

$$Ve = hf_{\max}$$

$$\text{or } Ve = \frac{hc}{\lambda_{\min}}$$

$$\text{or } \lambda_{\min} = \frac{hc}{Ve}$$

Putting values, we get

$$\lambda_{\min} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{40 \times 10^3 \times 1.6 \times 10^{-19}}$$

$$\lambda_{\min} = \frac{19.89 \times 10^{-26}}{64 \times 10^{-16}}$$

$$\boxed{\lambda_{\min} = 0.31 \times 10^{-10} \text{ m}}$$

20.10 The orbital electron of a hydrogen atom moves with a speed of $5.456 \times 10^5 \text{ ms}^{-1}$.

- Find the value of the quantum number n associated with this electron?
- Calculate the radius of this orbit.
- Find the energy of the electron in this orbit?

Given data:

$$\text{Speed of electron in } n\text{th orbit} = v_n = 5.456 \times 10^5 \text{ m/sec}$$



To find:

- (a) Value of quantum number = $n = ?$
- (b) Radius of n th orbit = ?
- (c) Energy of electron in n th orbit = $E_n = ?$

Calculations:

(a) Value of quantum number

$$\text{As } v_n = \frac{2\pi ke^2}{nh}$$

$$\text{or } n = \frac{2\pi ke^2}{V_n h}$$

Putting the values, we get

$$n = \frac{2 \times 3.14 \times 9 \times 10^9 \times (1.6 \times 10^{-19})^2}{5.456 \times 10^5 \times 6.63 \times 10^{-34}}$$

$$n = \frac{144.69 \times 10^{-29}}{36.173 \times 10^{-29}} = 3.999$$

$$\text{or } \boxed{n = 4}$$

(b) Radius of n th orbit

$$\text{As } r_n = \frac{n^2 h^2}{4\pi^2 k e^2 m}$$

$$\text{As } n = 4$$

$$\text{So } r_4 = \frac{(4)^2 h^2}{4\pi^2 k e^2 m}$$

Putting the values, we get

$$r_4 = \frac{16 \times (6.63 \times 10^{-34})^2}{4 \times (3.14)^2 \times 9 \times 10^9 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$$r_4 = \frac{16 \times 43.956 \times 10^{-68}}{4 \times 9.859 \times 9 \times 10^9 \times 9.1 \times 10^{-31} \times 2.56 \times 10^{-38}}$$

$$r_4 = \frac{703.296 \times 10^{-68}}{8268.309 \times 10^{-60}}$$

$$r_4 = 0.085 \times 10^{-8} = 0.85 \times 10^{-9} \text{ m}$$

$$\boxed{r_4 = 0.85 \text{ nm}}$$

(c) Energy of electron in n th orbit

$$\text{As } E_n = \frac{2\pi^2 k^2 m e^4}{n^2 h^2} \quad \text{But } n = 4$$

$$E_4 = \frac{2\pi^2 k^2 m e^4}{(4)^2 h^2}$$

Putting the values, we get



$$E_4 = \frac{2 \times (3.14)^2 \times (3 \times 10^9)^2 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^4}{(4)^2 \times (6.63 \times 10^{-34})^2}$$

$$E_4 = \frac{2 \times 9.859 \times 81 \times 10^{18} \times 9.1 \times 10^{-31} \times 6.4 \times 10^{-76}}{16 \times 43.956 \times 10^{-68}}$$

$$E_4 = \frac{93018.48 \times 10^{-89}}{703.296 \times 10^{-68}}$$

$$E_4 = \frac{93018.48}{703.296} \times 10^{-21}$$

$$E_4 = 132.26 \times 10^{-21} \text{ Joules}$$

or
$$E_4 = \frac{132.26 \times 10^{-21}}{1.6 \times 10^{-19}} \text{ eV}$$

$$E_4 = 82.66 \times 10^{-2} \text{ eV}$$

$$E_4 = 0.826 \text{ eV}$$

$$E_4 = 0.83 \text{ eV}$$



MCQ's From Past Board Papers

1. 3\AA is equal to :
 (a) $3 \times 10^{-10} \text{ m}$ (b) $3 \times 10^{-14} \text{ m}$ (c) $3 \times 10^{-12} \text{ m}$ (d) $3 \times 10^{-14} \text{ m}$
2. In the state $n = \infty$ of hydrogen atom, total energy of electron is:
 (a) 5.2 e V (b) 9.8 e V (c) Zero (d) 10.5 e V
3. The rest mass of x-ray photon is
 (a) Infinite (b) $9 \times 10^{-31} \text{ kg}$ (c) $1.67 \times 10^{-27} \text{ kg}$ (d) zero
4. Ratio of minimum to maximum wavelength in Balmer series is
 (a) 25/9 (b) 5/9 (c) 9/5 (d) 4/3
5. Reverse process of production of X ray is
 (a) Photoelectric effect (b) Compton effect (c) pair production (d) None
6. Process of forming 3D images by laser is
 (a) Spectroscopy (b) Holography (c) Radioactivity (d) None
7. As per Bohrs atomic model minimum energy required to remove electron form ground state of hydrogen atom is
 (a) 1.5ev (b) 3.4ev (c) 4.8ev (d) 13.6ev
8. In which region spectrum of hydrogen, The Blamer series lies
 (a) Infrared (b) Visible (c) Ultraviolet (d) Far ultraviolet
9. Radius of 3rd orbit of hydrogen atom is greater them radius of 1st orbittimes
 (a) 2 (b) 3 (c) 9 (d) 4
10. The residing time of atom in metastable state in case of LASER action
 (a) 10^{-5} s (b) 10^{-8} s (c) 10^{-4} s (d) 10^{-3} s
11. When X-rays are passed through successive aluminum sheets their hardness
 (a) Decreases (b) Increases (c) Remain same (d) none
12. Which is incorrect for X-rays
 (a) Damage living tissues (b) Ionization atoms through photoionization
 (c) Diffracted by crystal lattice (d) Cannot cause photo electric effect

13. **LASER Process involves**

(a) [Induced absorption
Spontaneous Emission]

(b) [Induced absorption
Simulated Emission]

(c) [Spontaneous absorption
Spontaneous Emission]

(d) [Spontaneous absorption
Induced Emission]

Answers Key

1.	a	2.	c	3.	d	4.	b	5.	a
6.	b	7.	d	8.	b	9.	c	10.	d
11.	a	12.	d	13.	b	14.	d		



IMPORTANT PREVIOUS BOARDS SHORT QUESTIONS

- Find the speed of the electron in the first Bohr orbit. (Lhr GI 2018)
- How can the spectrum of hydrogen contain so many lines, when hydrogen contains one electron? (Lhr GI 2018)
- What is population inversion? (Lhr GII 2018)
- What do we mean when we say that Atom is excited? (Bwp GI 2018)
- How LASER is used in medical? Give two uses only. (Mtn GI 2018) (Swl 2018) (Bwp GI 2018)
- Is energy conserved when an atom emits a photon of light? (Sgd GII 2018) (Rwp 2018) (Bwp GII 2018)
- What do we mean when we say that the atom is excited? (Mtn GII 2018) (Azad Kashmir 2018) (D.G.Khan GI 2018)
- State postulates of Bohr's Model of Hydrogen atom. (D.G.Khan GI 2018)
- Bohr's theory of Hydrogen atom is based upon several assumptions. Do any of these contradict classical physics? (D.G.Khan GII 2018)
- What are advantages of LASER over ordinary light? (Grw 2018) (Mtn GI 2018) (Bwp GII 2018) (Fsd 2018)
- Can electron reside inside the nucleus? Explain. (Fsd 2018)
- Define spectroscopy, holography. (Grw 2018)
- Write down two properties and two uses of x-rays. (D.G.Khan GII 2018) (Mtn GII 2018)
- Define Holography and Population inversion. (Sgd GII 2018)
- Can X-rays be reflected, refracted, diffracted and polarized just like any other wave? Comment on it. (Swl 2018)
- Define normal population and population inversion. (Rwp 2018)
- What do LED and LASER stand for? (Fsd 2018)

IMPORTANT PREVIOUS BOARDS LONG QUESTIONS

- What is meant by inner shell transition and characteristic X-rays? How X-rays are produced? Write down any two properties and uses of X-rays. (Lhr GI 2018) (Lhr GII 2018) (Bwp GI 2018)
- A tungsten target is struck by electrons that have been accelerated from rest through 400 kV potential differences. Find the shortest Wavelength of the Bremsstrahlung Radiation emitted. (Bwp GII 2018)
- Calculate the longest wavelength of radiation for the Paschen series. (D.G.Khan GII 2018)
- Compute the shortest wavelength of radiation in the Balmer series. What value of 'n' must be used? (Fsd 2018) (Grw 2018)
- Give the postulates of Bohr's theory and also give the de-Broglie's interpretation of Bohr's orbits. (Mtn GI 2018)
- Calculate the longest wavelength of radiation for the Paschen series. (Mtn GII 2018)
- What is LASER? Discuss the working of laser by explaining the stimulated emission of radiation and population inversion. (Sgd GII 2018)
- Compute the shortest and longest wavelength of radiation in the Lyman series. (Swl 2018)
- Write down the postulates of Bohr atom model for hydrogen atom. Also derive the formula for nth orbit radius of Bohr atom model and prove that the Bohr radii are quantized. (D.G.Khan GI 2018) (Rwp 2018) (Azad Kashmir 2018)

