Bohr’s Model of Atom

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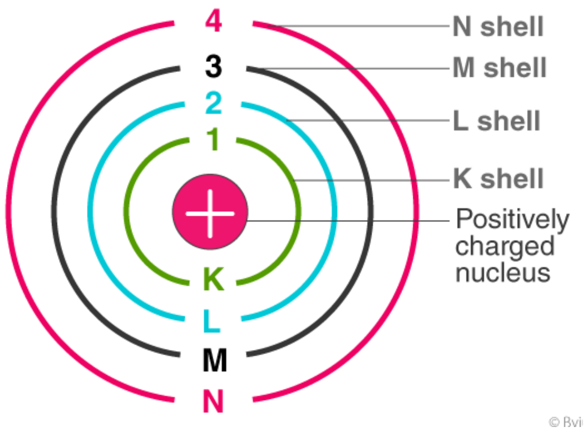
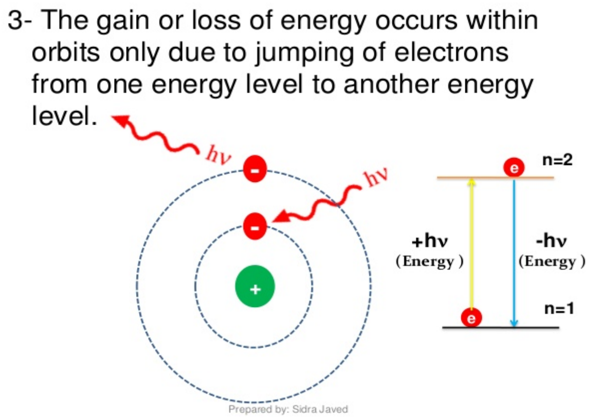
To overcome the limitation of the Rutherford’s Model of atom , Neil Bohr , in 1913 proposed a new model of atom on the basis of Planck’s quantum theory.

Main points-

(i) In an atom, the electrons revolve around the nucleus in certain definite circular paths called orbits.

(ii) Each orbit is associated with definite energy and therefore, these are known as energy levels or energy shells. These are numbered as 1,2,3,4, ----or K,L,M,N





(iii) only those energy orbits are permitted for the electron in which the angular momentum of the electron is a whole number multiple of h/2π ,

- angular momentum of electron (mvr)= nh/2π
- (n=1, 2, 3, 4 etc.) n= an integer
- m= mass of electron
- v= tangential velocity of the revolving electron
- r= radius of the orbit in which electron revolve
- h= Planck’s constant
- Angular momentum of the electron can be h/2π (n=1), 2h/2π if (n=2) , if n=3 , 3h/2π and so on. This means that the angular momentum of the electron is quantized.

(iv) As long as electron is present in particular orbit, it neither absorbs nor loses energy and its energy, therefore remain constant. These energy orbits are known as stationary states. Electrons are not stationary in the stationary states.

(v) When energy is supplied to an electron, it absorbs energy only in fixed amount as quanta and jumps to higher energy state away from the nucleus known as the excited state. Excited state is unstable. The electron may jump back to the lower energy state and in doing so, it emits the same amount of energy. ($\Delta E = E_2 - E_1$) The emission and absorption of energy can be take place only in certain fixed values equal to the energy difference of the two energy levels.

This means that the electron cannot move continuously but can jump from one energy level to the other. Therefore, energy of the electron is quantized.

Achievements of Bohr's Model of atom

1. Bohr's theory has explained the stability of an atom:

The electron present in a particular energy level cannot lose energy of its own. It can do so when it jumps from a higher energy level to the lower energy. In its stationary states, the electron keeps on revolving in the same circular orbit and does not come closer to the nucleus or lose energy as long as it stays in a particular orbit. Therefore, the question of losing energy continuously and falling into the nucleus does not arise.

2. Bohr's theory has helped in calculating the energy of electron in hydrogen atom and one electron species:-

Bohr's formula for calculating the energy of an electron in the nth orbit is:

- $E_n = -2\pi^2 me^4Z^2 / n^2h^2 = -1312xZ^2/n^2$
- m= mass of electron , e= charge of electron , h= Planck's constant , Z= atomic number
- For hydrogen atom Z =1
- $E_n = -1312X\,(1)^2/\,n^2 = -1312/n^2$ $kJmol^{-1}$
- If n=1, $E_1 = -1312$ $kJmol^{-1}$, n=2 $E_2 = -328$ $kJmol^{-1}$, n=3 $E_3 = -145.8$ $kJmol^{-1}$, n=4 $E_4 = -82.0$ $kJmol^{-1}$, n =5 $E_5 = -52.5$ $kJmol^{-1}$

Electronic energy as negative energy:

In the formula for the energy of the electron $E_n = -1312/n^2$ $kJmol^{-1}$, it has a negative value. When the electron is at distance infinity from the nucleus, there is no force of attraction on the electron by the nucleus. Its energy will be regarded as zero. As the electron moves towards the nucleus, it experiences a force of attraction by the nucleus. As a result, some energy is released. The energy of the electron will, therefore, become less than zero or becomes negative. Further, as the electron comes more and more close to the nucleus, attraction increases and more energy is released. Hence energy of the electron becomes less and less. This explains why the energy decreases as we move from the outer to the inner levels. Electronic energy has a negative sign in any energy level.

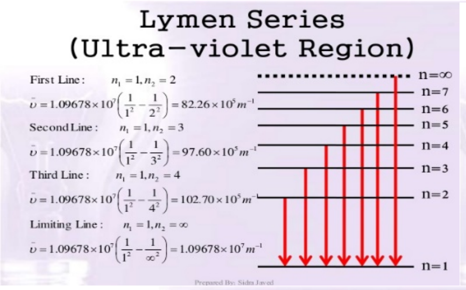
3. Bohr's theory has explained the atomic spectrum of hydrogen atom

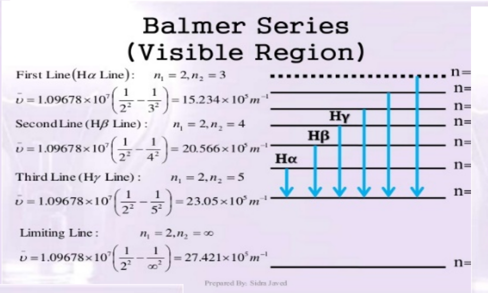
- Normally an electron tends to be as close to the nucleus as possible. It tends to be in the lowest energy state also called ground state. If electron absorbs energy from outside source in quantum, it jumps to the higher energy state known as excited state. **For example-** In hydrogen atom, the only one electron is present in the K-shell (n=1) in the ground state with energy E_1. If it absorbs energy equal to one quantum ($E = h\nu$). It jumps to the first excited state with energy equal to E_2. Since excited state is unstable, the electron will jump back to the ground state by losing a quantum of energy as radiations which appear as emission spectra. ($E_2 - E_1$)$= h\nu = hc/\lambda$. Emitted radiation having a definite frequency and wavelength.

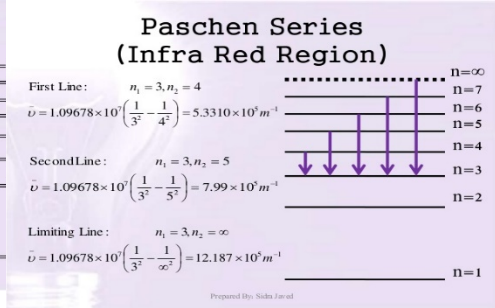
Simultaneous appearance of a large number of lines in the hydrogen spectrum

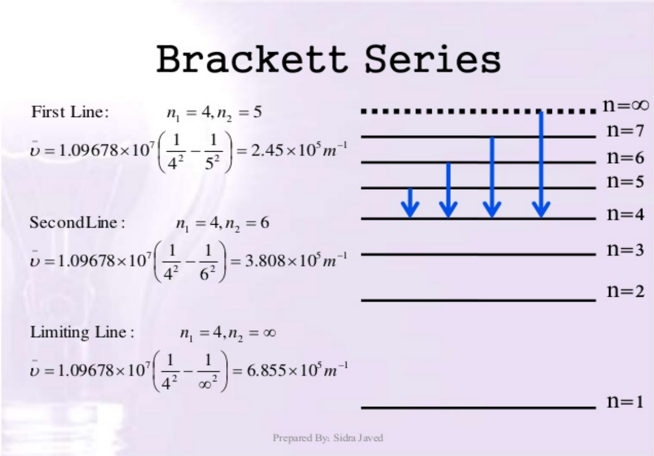
- Although an atom of hydrogen contains only one electron, yet its atomic spectrum consists of a large number of lines which have been grouped into five series -

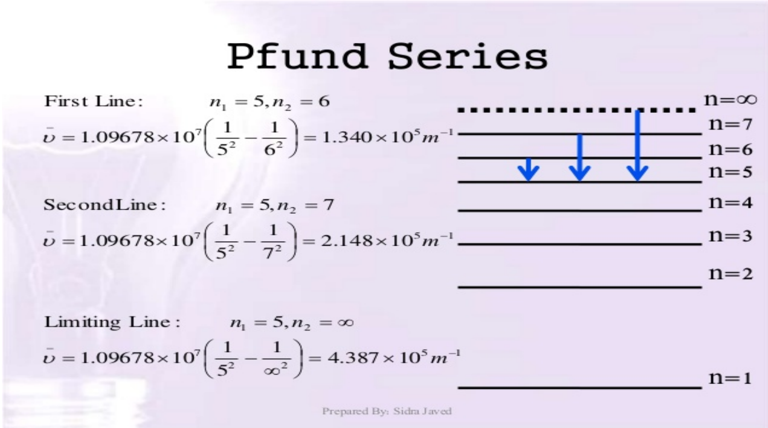
  1. Lyman series 2. Balmer series 3. Paschen series 4. Brackett series 5. Pfund series.











A sample of hydrogen gas contains a large number of molecules. When this sample is heated to a high temperature or an electric discharge is passed, the hydrogen molecules spilt into hydrogen atom. The electrons in different hydrogen atoms absorb different amounts of energies and are excited to different energy levels. The electrons in some atoms are excited to n=2, others to n=3, n=4, n=5 energy levels and so on. Since the excited states are unstable, the electrons jump back to the ground state. In the return journey, it is not necessary for all the electrons to follow the same route. For example- the electron is excited to higher energy level n=4, it may drop to the ground state(n=1) in one jump, in a particular atom. In the other atom, it may first jump to energy level n=3 and then to the ground state. Similarly, it can also first jump to the energy level n=2 and then to the ground state.

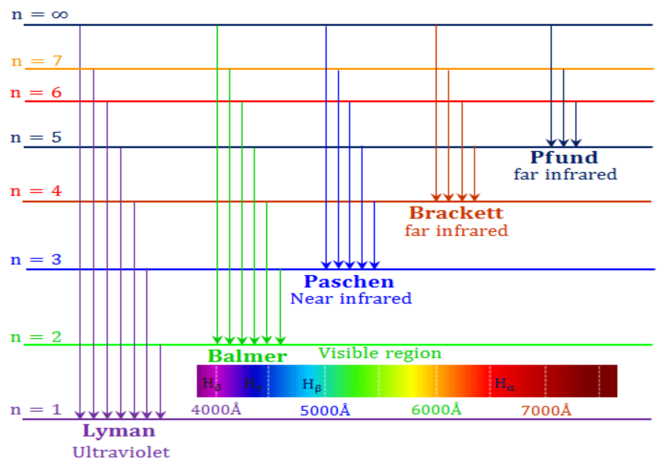
- **For example**- when the electron jumps from energy levels n=2, 3, 4, 5, 6, to n=1, the group of lines produced is called Lyman series. These lines lie in the ultraviolet region.

- Similarly, the group of lines produced when electron jumps from 3rd, 4th, 5th, or any higher energy level to 2nd energy level is called Balmer series. These lines lie in the visible region.

- Paschen series are obtained by electronic jumps from 4th, 5th or any higher level to the 3rd energy level.

- Brackett series results from electronic transition from 5th,6th or any higher energy level to the 4th energy level.

- Lastly, the Pfund series originates by electronic jumps from 6th, 7th or any higher energy level to 5th energy level. These three spectral lines lie in the infrared region.



Assignments

1. In the Bohr's orbit, the ratio of total kinetic energy and the total energy of the electron is---
(a) -2 (b) -1 (c) +2 (d) 0

2. The spectral line in hydrogen spectrum obtained when the electron jump from n = 5 to n=2 energy level belongs to ---
(a) Lyman series (b) Balmer series (c) Paschen series (d) Pfund series

3. The line spectrum observed when electron jumps from higher level to M level is known as ---
(a) Balmer series (b) Lyman series (c) Paschen series (d) Brackett series

4. The energy of the electron in the nth orbit of hydrogen atom is given as: $E_n = -\ 1312/n^2\ kJmol^{-1}$ what is the energy emitted per atom when an electron jumps from third level to second energy level?
(a) 329.7 kJ (b) $3.03x\ 10^{-19}J$ (c) 182.2kJ (d) 145.7kJ

5. In hydrogen atom, energy of the first excited state is -3.04eV. Then find out the K.E of the same orbit of H-atom.
(a) +3.4eV (b) +6.8eV (c) -13.6eV (d) +13.6eV

6. The frequency of radiation emitted when the electron falls from n=4 to n=1 in a hydrogen atom will be (given ionization energy of H = $2.18x\ 10^{-18}$ J atom^{-1} and h=$6,625x10^{-34}$ Js)
(a) $1.03x\ 10^{3}s^{-1}$ (b) $3.08\ x\ 10^{15}s^{-1}$ (c) $2.00\ x10^{15}s^{-1}$ (d) $1.54\ x\ 10^{15}s^{-1}$

7. The energy of second Bohr orbit of the hydrogen atom is – 328kJ mol^{-1} hence the energy of fourth Bohr orbit would be ----
(a) -41kJ /mol (b) -82kJ/mol (c) -164kJ/mol (d) 1312kJ/mol

8. According to Bohr's theory, the angular momentum of an electron in 5th orbit is -----
(a) 1.0h/π (b) 10h/π (c) 2.5 h/π (d) 25 h/π

9. What is the maximum number of emission lines obtained when the excited electrons of a hydrogen atom in n=5 drop to ground state?
(a) 10 (b) 5 (c) 12 (d) 15

10. The electronic transitions from n=2 to n= 1 will produce shortest wavelength in ----
(a) Li^{+2} (b) He^{+} (c) H (d) H^{+}

Answers:

1. (b) 2. (b) 3. (c) 4. (b) 5. (a) 6. (b) 7. (b) 8. (c) 9. (a) 10. (c)

Author is M.Sc. (Chem.), M.Ed. and Advanced Diploma in German Language (Gold Medallist). She retired as a Principal, Govt. School Haryana, has 3-1/2 years' experience in teaching Chemistry and distance teaching through lectures on Radio and Videos. She has volunteered to complement mentoring of students for Chemistry through Online Web-enabled Classes of this initiative.

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