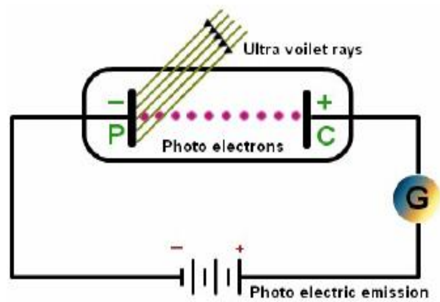
Photoelectric effect

Photoelectric effect is the process of emitting the electrons from the metal surface when the metal surface is exposed to an electromagnetic radiation of sufficiently high frequency. For example, ultraviolet light is required in the case of ejection of electrons from an alkali metal.

Photoelectric effect can be explained by the following equation



$$E(=h\nu) = h\nu_0 + T_{max}$$

$E=h\nu$ is the photon energy

Here

E is the total energy of the photon incident on the metallic surface,

ν is the frequency of the incident radiation,

ν_0 is the threshold frequency of the metal and

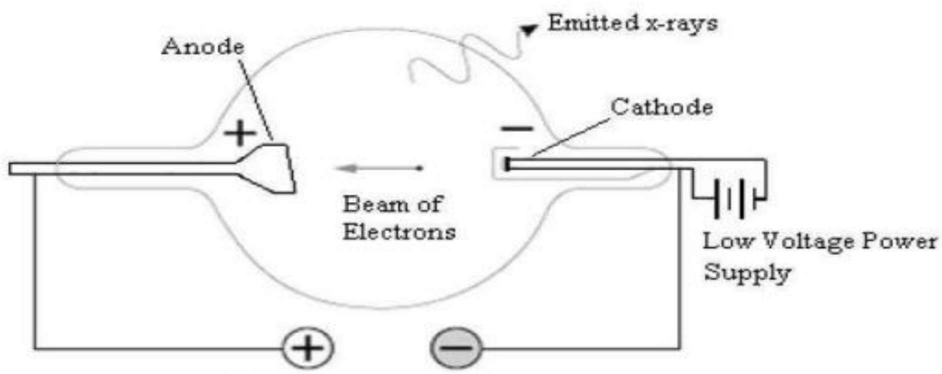
T_{max} is the maximum kinetic energy with which the electron moves after ejection from the surface.

increase in intensity implies increasing the number of photons leading to increase in number of collisions with the electrons and their subsequent ejection from the surface. This then should increase the photocurrent. Thus increase in intensity should increase the photocurrent.

When frequency is increased the energy of individual photons increases. The work function is fixed. Hence, the any increase in the energy of individual photons results in increase in maximum kinetic energy of the ejected electrons.

Production of X-rays

An X-ray tube is a vacuum tube designed to produce X-ray photons. The first X-ray tube was invented by Sir William Crookes. The Crookes tube is also called a discharge tube or cold cathode tube. A schematic x-ray tube is shown below.



The glass tube is evacuated to a pressure of air, of about 100 pascals

The anode is a thick metallic target, a high voltage, between 30 to 150 kV, is applied between the electrode

When these electrons hit the target, they are slowed down, producing the X-rays

The radiation energy from an X-ray tube consists of discrete energies constituting a line spectrum and a continuous spectrum providing the background to the line spectrum.

Properties of X-rays

X-rays travel in straight lines.

X-rays cannot be deflected by electric field or magnetic field. X-rays have a high penetrating power.

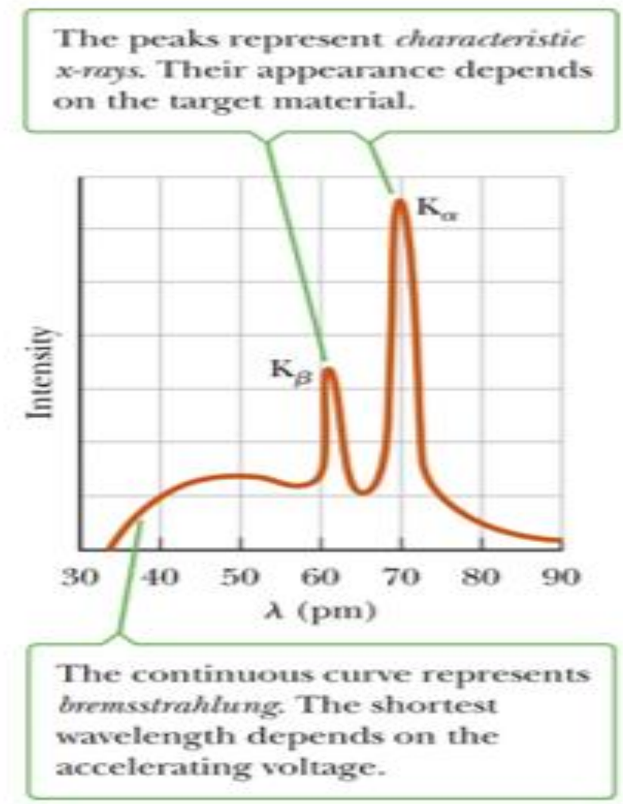
Photographic film is blackened by X-rays.

Fluorescent materials glow when X-rays are directed at them.

Photoelectric emission can be produced by X-rays.

Ionization of a gas results when an X-ray beam is passed through it.

- When a metal target is bombarded by high-energy electrons, x-rays are emitted
- The x-ray spectrum typically consists of a broad continuous spectrum and a series of sharp lines
  - The lines are dependent on the metal of the target
  - The lines are called *characteristic x-rays*

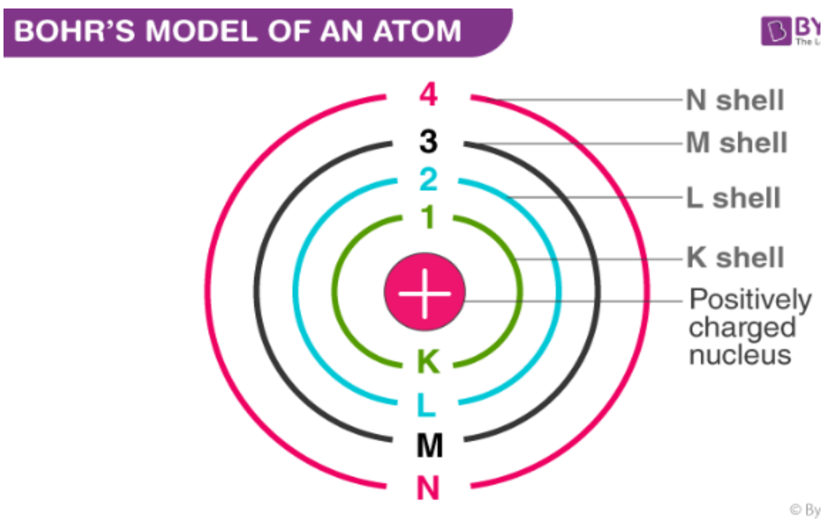


Bohr's Model Of An Atom

The Bohr model of the atom was proposed by Neil Bohr in 1915. It came into existence with the modification of Rutherford's model of an atom. Rutherford's model introduced the nuclear model of an atom, in which he explained that a nucleus (positively charged) is surrounded by negatively charged electrons

Bohr theory modified the atomic structure model by explaining that electrons move in fixed orbitals (shells) and not anywhere in between and he also explained that each orbit (shell) has a fixed energy. Rutherford explained the nucleus of an atom and Bohr modified that model into electrons and their energy levels.

Bohr’s model consists of a small nucleus (positively charged) surrounded by negative electrons moving around the nucleus in orbits. Bohr found that an electron located away from the nucleus has more energy, and the electron which is closer to nucleus has less energy

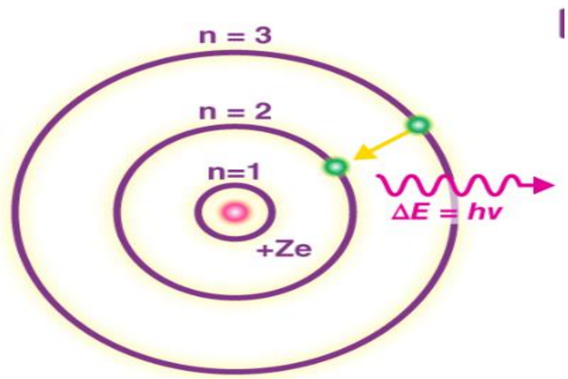


Bohr’s Model of an Atom

Postulates of Bohr’s Model of an Atom

- in an atom, electrons (negatively charged) revolve around the positively charged nucleus in a definite circular path called orbits or shells.
- Each orbit or shell has a fixed energy and these circular orbits are known as orbital shells.
- The energy levels are represented by an integer (n=1, 2, 3…) known as the quantum number. This range of quantum number starts from nucleus side with n=1 having the lowest energy level. The orbits n=1, 2, 3, 4… are assigned as K, L, M, N…. shells and when an electron attains the lowest energy level, it is said to be in the ground state.

- The electrons in an atom move from a lower energy level to a higher energy level by gaining the required energy and an electron moves from a higher energy level to lower energy level by losing energy.

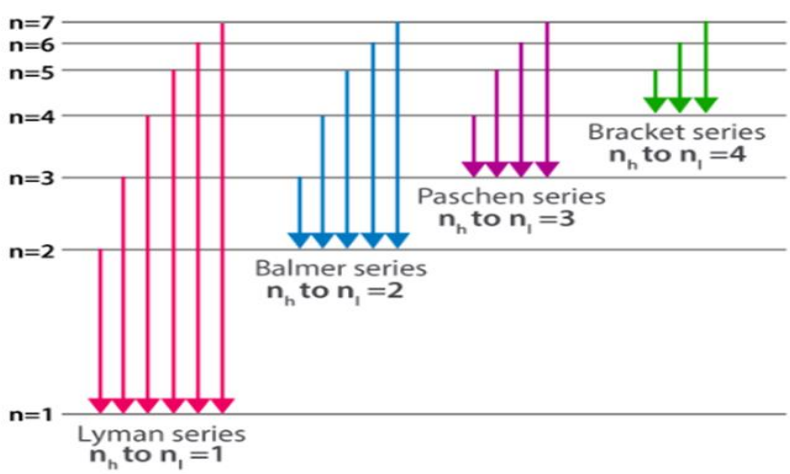


<u>Limitations of Bohr's Model of an Atom</u>

- Bohr's model of an atom failed to explain the Zeeman Effect (effect of magnetic field on the spectra of atoms).
- It also failed to explain the Stark effect (effect of electric field on the spectra of atoms).
- It violates the Heisenberg Uncertainty Principle.
- It could not explain the spectra obtained from larger atoms.

<u>Spectrum of Hydrogen Atom</u>

- ***<u>Emission spectrum of hydrogen</u>***



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Rydberg formula

The emission spectrum of atomic hydrogen has been split into several spectral series, with wavelengths given by the Rydberg formula. The energy differences between levels in the Bohr model, and therefore the wavelengths of emitted or absorbed photons, is given by the Rydberg formula:

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

where

- Z is the atomic number,
- n_1 is the principal quantum number of the lower energy level,
- n_2 is the principal quantum number of the upper energy level,
- R is the Rydberg constant. $(1.09677\times10^7\ m^{-1}\ for\ hydrogen\ and\ 1.09737\times10^7\ m^{-1}\ for\ heavy\ metals)$.

Emission spectrum of hydrogen

The spectral lines are grouped into series according to n′. Lines are named sequentially, starting from the most comprehensive wavelength or lowest frequency of the series, using Greek letters within each series.

Lyman series

- The series was discovered during the years 1906-1914, by Lyman. Thus it is named after him. According to Bohr's model, Lyman series is displayed when electron transition takes place from higher energy states(n=2,3,4,5,6,…) to n_l=1 energy state. All the wavelength of Lyman series falls in Ultraviolet band.

Balmer series

- The series was discovered during the years 1885, by Johann Balmer. Thus the series is named after him.
- Balmer series is displayed when electron transition takes place from higher energy states(n=3,4,5,6,7,…) to nl=2 energy state. All the wavelength of Balmer series falls in

visible part of electromagnetic spectrum (400nm to 740nm). In astronomy, the presence of Hydrogen is detected using H-Alpha line of the Balmer series, it is also a part of the solar spectrum.

Paschen series

- The series was first observed during the years 1908, by a German physicist Friedrich Paschen. Thus the series is named after him. Paschen series is displayed when electron transition takes place from higher energy states(n=4,5,6,7,8,…) to nl=3 energy state. All the wavelength of Paschen series falls in the Infrared region of the electromagnetic spectrum. The shortest wavelength of next series, i.e., Brackett series overlap with Paschen series. From this series, all subsequent series overlap.

Brackett series

- The series was first observed during the years 1922, by an American physicist Friedrich Sumner Brackett. Thus the series is named after him. Brackett series is displayed when electron transition takes place from higher energy states (n=5,6,7,8,9…) to nl=4 energy state. All the wavelength of Brackett series falls in Infrared region of the electromagnetic spectrum.

Pfund series

- The series was first observed during the years 1924, by August Harman Pfund. Thus, the series is named after him. Pfund series is displayed when electron transition takes place from higher energy states(n=6,7,8,9,10,…) to nl=5 energy state. All the wavelength of Pfund series falls in Infrared region of the electromagnetic spectrum.

Humpfrey's series

- The series was first observed during the years 1953, by an American Physicist Curtis J Humphreys, thus the series is named after him. Humphreys series is displayed when electron transition takes place from higher energy states(n=7,8,9,10,11…) to n_l=6 energy state. All the wavelength of Humphreys series falls in Infrared region of the electromagnetic spectrum.

Further series

- They are the unnamed series, which follow the spectral pattern described by the Rydberg equation. They are first observed in infrared range during an experiment in 1972 by Peter Hanson and John Strong. These series are displayed when electron transition takes place from higher energy states(n=8,9,10,11…) to nl=7 or above energy state. The series is observed in higher wavelength. The spectral lines are extremely faint and widely spread out. They correspond to highly rare atomic events.
- It has been found by experimental methods that the first spectral line of each series is the lowest in energy and the longest in wavelength, which means that the relationship between energy and wavelength is a inverse relationship

mass and total energy

In particle physics, we often deal with particles travelling close to the speed of light; photons of course always go at the speed of light! Hence, we need to review the formulæ for relativistic kinematics.

Calculate the wave length of the first, the second and the third line of Lyman series, Balmer series, and Paschen series