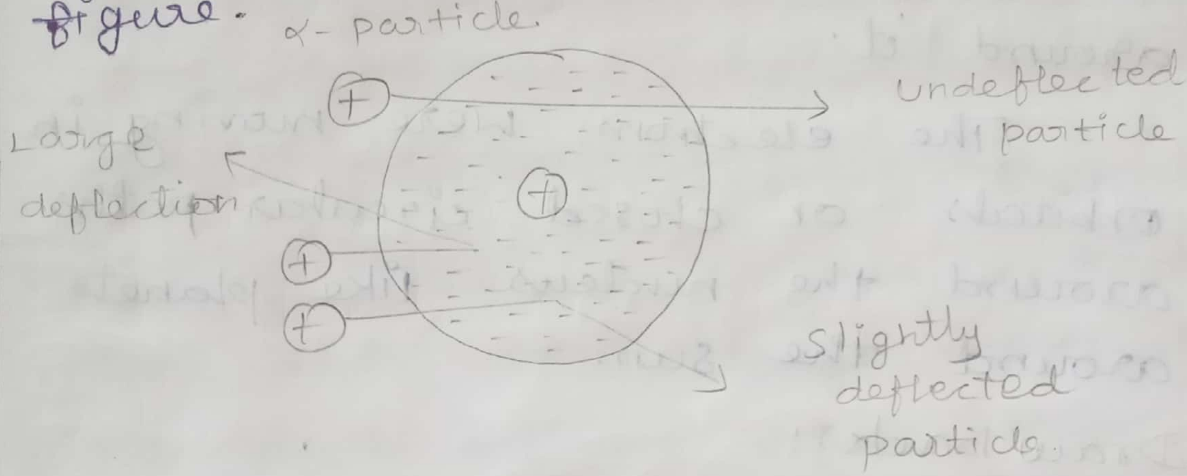
Atomic Structure

Rutherford's Atom model:

Rutherfoord a stream of highly energetic α-particles from a radio active source against a thin gold fail. After passing through the metal sheet the α-particles struck a zinc sulphide screen. The course of α-particle striking sheet is represented in the figure.



Most of the α-particle were to pass through the sheet with no change in their path. But a few were deflected from their original path through 90° or even wider angles and some of them were even deflected almost backwoards. Based on theses observations, he propsed a model of atom called Nuclear atom. According to his theory.

Atom has a tiny dense central core or the Nucleaus which contains practically the entire mass of the atom, leaving the rest of the atom, almost empty.

The entire positive charge of the atom is located on the nucleus while electrons were distributed in vacant space around it.

The electrons were moving in orbitals or closed circular paths around the nucleus like planets around the sun.

Draw backs:

it could not explain line spectra of atom.

It could not explain stability of an atom because this model does not obey Maxewell law of electro-dynamics. According to Maxewell electron should continuous emit radiation and thus and gradually lose energy, so its distance from nucleus should become shorter and finally it should fall into the nucleus.

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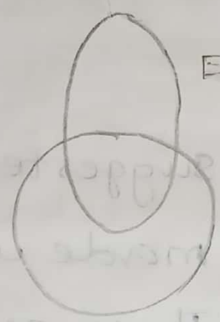
Sommerfeld's Atom model:

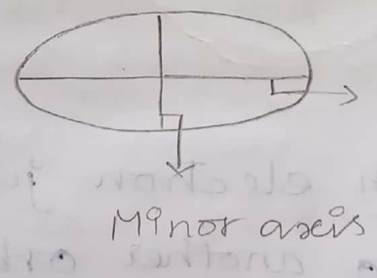
~~The~~ This model explains the fine spectrum of Hydrogen atom. The important postulates of Sommor feld atomic model are.

1) The orbitals may be both circular or elliptical.

2)



2) When path is elliptical, then there are two axis - major axis & minor axis. When length of major & minor axis become equal then orbit is circular.



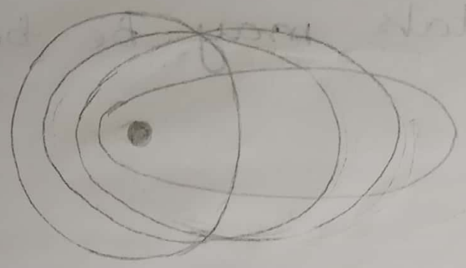
3) The angular momentum of electron moving in an elliptical ~~orbital~~ orbital $kh/2\pi$.

k is integer except zero.

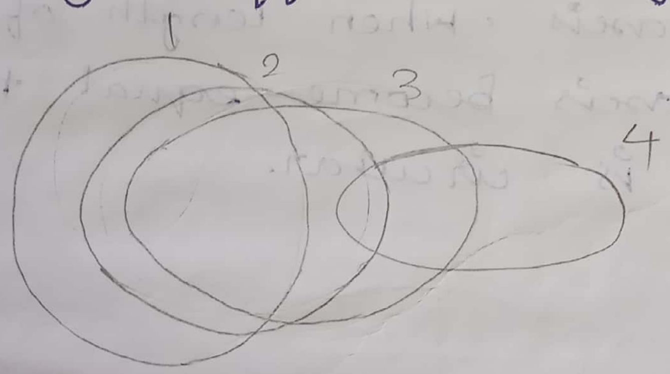
Value of $k = 1, 2, 3, 4 \ldots$

n/k = Length of major axis / Length of minor axis.

With increase is value of k, ellipticity of the orbit decreases. When n = k then orbit is circular



Sommerfeld suggested that orbitals are made up of sub energy levels. These are s, p, d, f. These sub shells posses slighlty different energies.



When an electron jumps from one orbit to another orbit, the difference of energy (ΔE) depends upon sub energy levels.

It explains the spiltting of individual spectral lines of hydrogen & thus fine spectrum.

It could not predict the exact number of lines which are actually present in the fine spectrum.

Defects of sommerfeld atomic model :-

This model does not explain the behaviour of system having more than one electron.

This model does not explain the Zeeman & stark effect.

Bohr's Atom model :

Bohr's theory is based on the following postulates;

1. Bohr considered the atom to consist of a positively charged nucleus with electrons revolving around it.

2. Electrons can move around the nucleus only in certain definite orbits. Electrons in each orbit have a definite energy and are at a fixed distance from the nucleus.

The orbits are designated K, L, M, N etc or 1, 2, 3, 4 etc.

While in these specific orbits, an electron does not radiate energy. Therefore in each of these orbit, the energy of an electron remains the same. Hence an orbit is called stationary energy level or energy level.

An electron can move from one energy level to another by quantum or photon jumps only. An electron in its lowest energy said to be in the ground state. When an e^- is supplied with energy, it absorbed one quantum or photon of energy and jumps to higher energy level. The e^- is then said to be in excited state. The quantum of energy absorbed or emitted is equal to the energy diff b/w the lower & higher energy levels of the atom.

$$\Delta E = E_2 - E_1 = h\nu$$

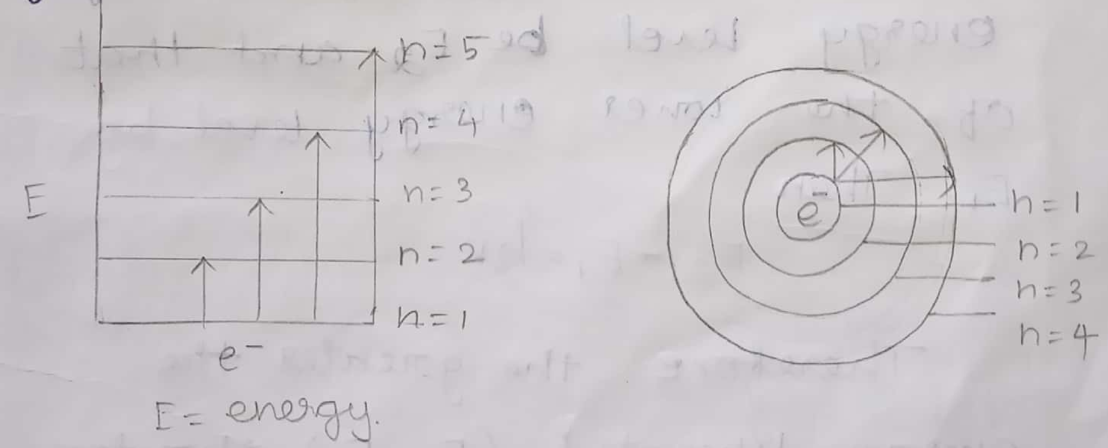
The angular momentum mvr, of an electron orbiting around the nucleus is an integral multiple of plank's constant divided by 2p.

$$mvr = n\frac{h}{2\pi}$$

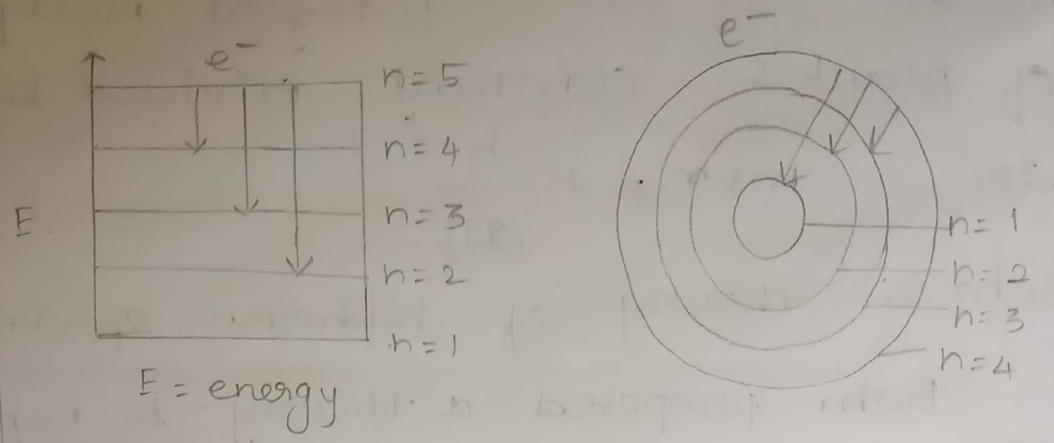
Bohr's theory of hydrogen spectrum:

Bohr proposed a theory to explain the emission of line spetra from hydrogen atom.

Let us consider a hydrogen atom in the ground state. The e^- is in the first k - energy shell. if it absorbs energy the electron moves into a higher energy level. depending upon the energy absorbed by it.



The atom is an excited state now. This is an unstable situation.



The electron therefore falls back almost immediately to one of the lower levels. or even to the ground state. The diff in the energy proposed by the electron in the level and the lower level is emitted by the atom in the form of the line spectrum.

Let the energy of the higher energy level be E_2 and that of the lower energy level by E_1. Then

$$E_2 - E_1 = h\nu$$

Therefore the greater the energy liberated $(E_2 - E_1)$ shorter will be the wave length of the emitted radiation.

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Hydrogen atoms contains only one electron. But its spectrum consists of a large no. of lines. According to Bohr ~~and~~ the reason for this is given as follows,

A sample of hydrogen contains a very larger no. of atoms. When energy is supplied to the sample of gas. different atoms absorb diff amounts of energies. so electron is different atoms will move up to different energy levels denpending up on the energy absorbed by the atoms. So when electrons fall, back they fall from different energy levels and reach different energy levels. We get several spectral lines with varied wave lengths.

Electromagnetic radiation:-

EM radiation can Be defind as a form of energy that is produced By the ~~p~~ movement of electrically charged particles travelling through a matter or vaccum or by osillating mignetic and electric disturbance. ~~The magnetic and the~~

Electromagnetic theory:

It's study deals with how the electrically charged particles interact among themselves and with the magnetic field. The main electromagnetic interactions are provided in the points mentioned below,

Magnetic poles come in pairs the repel and attract each other, just like electric chrages do.

The force of repulsion or attraction between two electric charges is invesely proportional to square of the distance b/w the particles.

An electric field in motion producess a magnetic field.

A wire with electric current produces a magnetic field whose direction depends on the direction of the electric current

Properties of electro magnetic radiation:

When EM radiation occurs, the electron radiation are released a photons. ~~These are~~ Then based on the wavelength of the electromagnetic spectrum the energy is grouped into different categories. These magnetic and electric waves travel perpendicular to each other and have some characteristics like wavelengh, amplitude, frequency.

They can travel through empty space. waves other than electro magnetic waves have to travel through some substance.

Wavelength is commonly charaterised by the symbol 'λ'.

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Wavelength:

wavelength (λ) is the distance between successive crests of a wave especially points in an electromagnetic wave or sound wave.

$$c = \lambda v$$

if 'λ' is the wavelength 'c' is the speed of light and 'v' is frequency.

Frequency:

The no. of cycles per second is defind as Frequency.

$$E = hv$$

'h' is the plank's constant. 'v' is a frequency.

velocity:-

In relation with electro-magnetic radiation the velocity is normally expresses as;

velocity = λv

Heisenberg's Uncertainty principle:-

Heisenberg's Uncertainty principle states that it is not possible to know both the position and momentum of a moving particle at the same time.

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x \, m \Delta u \geq \frac{h}{4\pi}$$

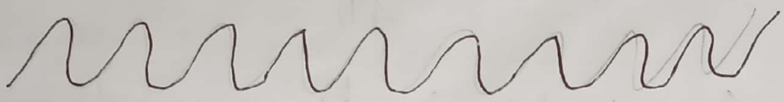
x = Position
u = speed
p = momentum

The more accurately we know the speed, the less accurately we know the position, and vice versa.

Black-Body Radiation:

In 1900 Max plank's studied the spectral lines obtained from Black-Body radiation, at diff temparature. He proposed a new theory that a hot body radiant energy not in continuous waves but in small units of waves but is small units of waves are called quantum.

i) Radiant energy is absorbed or emitted by a body not as continuous waves but as small packets of the waves called quantum.



continious wave

quantum

ii) The energy associated with each quantum is proportional to the frequency of the radiation.

$E \propto \nu$ (or) $E = h\nu$

Where h = plank's constant (6.625×10^{-27} erg sec.)

This equation is called plank's equation. Since,

$\nu = c/\lambda$

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

Where c = velocity of radiation,
λ = wavelength of radiation.

iii) A body can absorb or emit only one quantum of energy or some whole number multiple of it. Energy less than a quantum is neither absorbed nor emitted. That is,

$E = nh\nu$, where $n = 1, 2, 3 \ldots$

photo electric effect:

When a beam of light of sufficiently high frequency is allowed to strike a metal surface in vaccum electrons are ejected from the metal surface. This phenomenon is known as photoelectric effect and the ejected electrons are called photo electrons. For ex; when ultraviolet light is passed on cs the photoelectric effect occurs. A study of photoelectric effect leads to the following conclusions.

1. An increase in the intensity of incident light does not increase the energy of the photoelectrons. It merely increases their rate emission.

2. The kinetic energy of the photoelectrons increase linearly with frequency of the incident light. If the frequency is decreased below a certain value. no no electrons are ejected at all.

Debroglie theory:

According to Debroglie every material particle is associated with a wave. He proposed a relation between the momentum and of wavelength of particle in motion.

Derivation:

According to plank's quantum theory of radiation the energy of a photon is equal to $h\nu$.

$$E = h\nu$$

Since $\nu = \frac{c}{\lambda}$; $E = h\frac{c}{\lambda}$

According to Einstein's mass energy relationship.

$$E = mc^2$$

Comparing the above two equations;

$$mc^2 = \frac{c}{\lambda} \; ; \left[\therefore mc = \frac{h}{\lambda} \right]$$

or momentum $p = \frac{h}{\lambda}$; $\lambda = \frac{h}{p}$

This is the fundamental equation of De Broglie. This gives the wave length λ of the matter wave associated with material particles. Since material particle had were characteristics they were referred to as matter waves.

The above relations is applicable to any particle having a mass m and moving with a velocity v. Now the equation becomes.

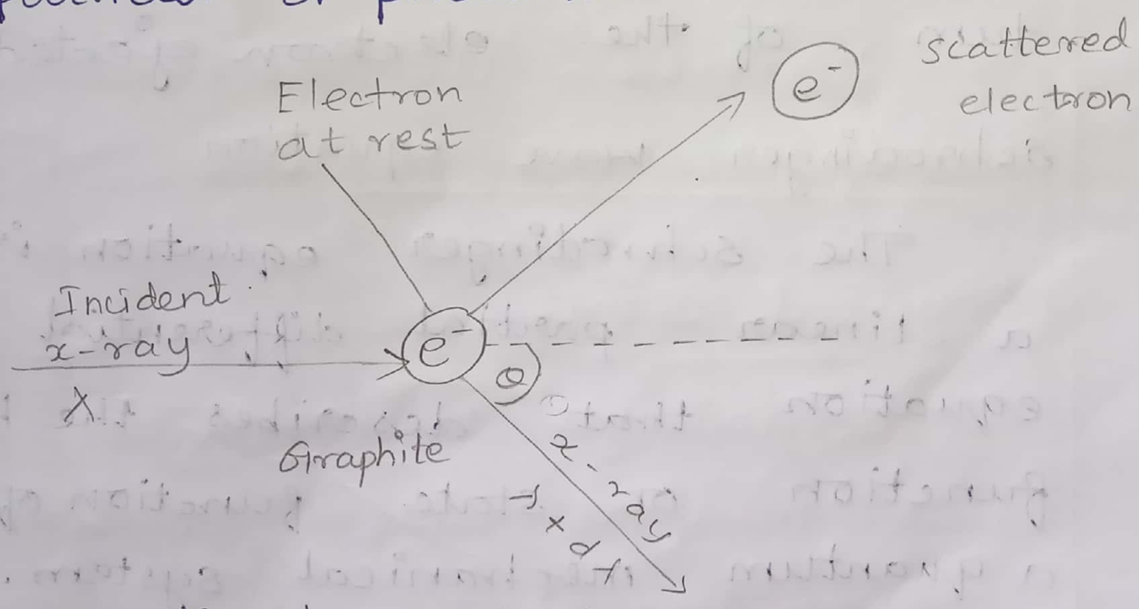
$$\lambda = \frac{h}{mv}$$

Compton effect:

When x rays of wavelength λ' struck a sample of graphite an electron was ejected and the x-rays scattered at an angle θ had longer wavelength λ

~~Defi~~ Explanation of compton Effect:

Compton said that it was like a ball hitting a stationary ball which is pushed away while the energy of the striking ball decreases. Thus he argued that light radiation consisted of particles, as a continuous wave could not have knocked out the electron. He visualised that a photon of incident light struck a stationary electron in graphite and hence lost some energy which resulted in the increase of wavelength. This process could not have occured unless light radiation consisted of particles or photons.



Compton scattering of x-rays.

By assuming photon-electron collisions to be perfectly elastic, Compton found that the shift in wavelength, $d\lambda$ was given

$$d\lambda = \frac{2h}{mc} \sin^2 \theta/2$$

h is plank's constant, m the mass of an electron, c the velocity of light θ the angle of scattering. The expression shows that dλ is independent of the nature of the substance and wavelength of the incident radiation. Given the wavelength of a photon. One can calculate the momen-tum of the electron ejected

Schrodinger wave equation

The schrodinger equation is a linear partial differential equation that describes the wave function or state function of a quantum mechanical system. The equation named after 'Erwin Schrodinger, who postulated the equation in 1925.

The schrodinger equation in One dimension is

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}(E-U)\psi = 0$$

The most general form schrodinger equation in three dimensional space can be written as

$$\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} + \frac{8\pi^2 m}{h^2}(E-U)\psi = 0$$

This equation is called the schrodinger wave equation. The first three terms on the left hand side are represented by

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-U)\psi = 0$$

$$\nabla^2 = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}$$

∇^2 is known as Laplacian operator

$$\nabla^2 \varphi = \frac{d^2\varphi}{dx^2} + \frac{d^2\varphi}{dy^2} + \frac{d^2\varphi}{dz^2}$$

x, y and z are the displacements in three directions

φ = A mathamatical function representing the amplitude of the wave ; m = mass of the particle ; h = plank's constant ; E = total energy of particle ; U = The potential energy of the particle.

Physical significance :

Schrodinger wave function has multiple unique solutions representing characteristic radius, energy, amplitude. probability density of the electron calculated from the

Wave function shows multiple orbitals with Unique energy and distribution in space.

Schrodinger equation could explain the presence of multiple orbitals and the fine spectrum arising out of all atoms, not necessarily hydrogen like atoms.