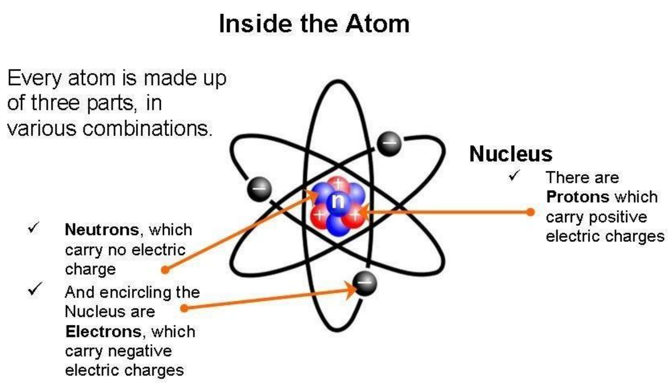
Drawbacks of Rutherford's atomic model

The orbital revolution of the electron is not expected to be stable. According to Rutherfords model, the electrons, while moving in their orbits, would give up energy. This would make them slow down, gradually and move towards the nucleus. The electrons will follow a spiral path and then fall into the nucleus. Ultimately, the atom would collapse. But in reality the atom is stable.

Nucleus



Nucleus refers to the small dense region, in which positively charged protons and electrically neutral neutrons are present. Electrons revolve around the nucleus in fixed orbits.

Extra-nuclear part

Almost the entire mass of the atom is concentrated in a very small part of its total size. This part is called nucleus and all protons and neutrons are embedded in it. Most of the atom is without any mass is called extra-nuclear part. This extra nuclear part contain circular orbits in which electrically negative charged electrons revolves.

Definition of Isotopes

Isotopes are atoms of the same element having the same atomic number (Z) but different mass numbers (A).

Uses of isotopes

An isotope of uranium is used as fuel in a nuclear reactor.
An isotope of cobalt is used in the treatment of cancer.
For treating goitre, an isotope of iodine is used.

Properties of isotopes

Isotopes have similar chemical properties.The chemical properties of an element depend on the number of electrons present and their configuration within an atom and not on the number of neutrons, as the isotopes have the same number of electrons; they exhibit similar chemical properties. Isotopes of an element exhibits different physical properties because of difference in mass number. For example the boiling point of protium is 20.38 K where as, the boiling point of deuterium is 23.5 K.

Isobars

Atoms of different elements with different atomic numbers but the same mass numbers are called isobars. Isobars have different chemical properties because they have different atomic numbers.

Solve questions on isobars

Calculate number of electron present in Argon and potassium.
Solution : As argon and potassium are isobars they have same mass number but different atomic number. Hence electron present in Ar is 18 and in potassium is 19.

Developments leading to the Bohr's model of atom

It is observed that all elements give characteristics line spectra which could not be explained on the basis of Rutherford's model. For this, it is essential to understand the nature of light for which electromagnetic theory and Plank's quantum theory is necessary. Hence a new model called Bohr's model of atom was put forward.

Corpuscular theory

This theory proposed that matter to be composed of minute particles. In optics, the **corpuscular theory** of light, arguably set forward by Pierre Gassendi and Thomas Hobbes, states that light is made up of small discrete particles called "corpuscles" (little particles) which travel in a straight line with a finite velocity and possess impetus.

Concept behind EM wave theory

In the early 19th century, the English scientist Thomas Young carried out the famous double-slit experiment which demonstrated that a beam of light, when split into two beams and then recombined, will show interference effects that can only be explained by assuming that light is a wavelike disturbance. By 1820, Augustin Fresnel had put this theory on a sound mathematical basis, but the exact nature of the waves remained unclear until the 1860's when James Clerk Maxwell developed his electromagnetic theory. But Einstein's 1905 explanation of the photoelectric effect showed that light also exhibits a particle-like nature. The photon is the smallest possible packet (*quantum*) of light; it has zero mass but a definite energy.

Wavelength

Wavelength is defined as the distance between any two consecutive crests or troughs. It is represented as λ and is expressed in Angstrom or m or cm or nm or pm.

Frequency

It is the defined as the number of waves passing through a point in one second. It is represented by ν and is expressed in Hertz(Hz) or cycles per sec or simply s^{-1}.

Velocity

It is defined as the linear distance traveled by the wave in one second. It is represented by c and is expressed in cm/sec or m/sec.

Amplitude

It is the height of the crest or the depth of the trough. It is represented by 'a' and is expressed in the unit of lengths.

Limtations of electromagnetic wave theory

It could not explain the following:

The phenomenon of black body radiation
The photo electric effect
The variation of heat capacity of solids as a function of temperature
The line spectra of atoms with special reference to hydrogen

Black body radiation and its properties

Black-body radiation is the type of electromagnetic radiation within or surrounding a body in thermodynamic equilibrium with its environment, or emitted by a black body (an opaque and non-reflective body) held at constant, uniform temperature.
The properties are:
1. Hotter objects emit more light at all wavelengths per unit area.
2. Hotter objects emit photons with a higher average energy.

Photoelectric effect

The photoelectric effect or photo emission is the production of electrons or other free carriers when light shines upon a material. Electrons emitted in this manner can be called photo electrons.

Photoelectrons

The photoelectric effect states that electrons can be pushed off the surface of a solid by electromagnetic radiation. The ejected electronsare called photoelectrons.

Threshold frequency

Threshold frequency is defined as the minimum frequency of incident light which can cause photo electric emission i.e. this frequency is just able to eject electrons with out giving them additional energy.

Work function

The work function (sometimes spelled work function) is the minimum thermodynamic work (i.e. energy) needed to remove an electron from a solid to a point in the vacuum immediately outside the solid surface.

Dual nature of EM waves

EM radiation is so-named because it has electric and magnetic fields that simultaneously oscillate in planes mutually perpendicular to each other and to the direction of propagation through space. Electromagnetic radiation has the dual nature: its exhibits wave properties and particulate (photon) properties.

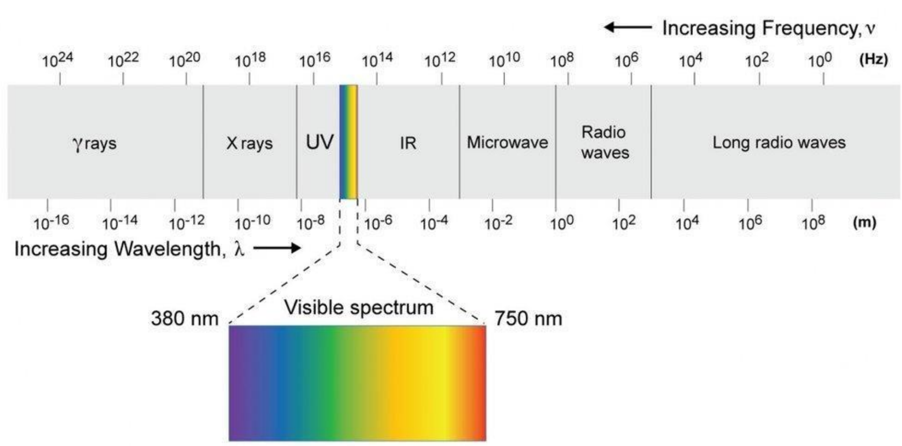
Spectroscope

A spectroscope is an instrument used to break light up into its constituent colors, like a prism does, showing the light spectrum.

Spectroscopy

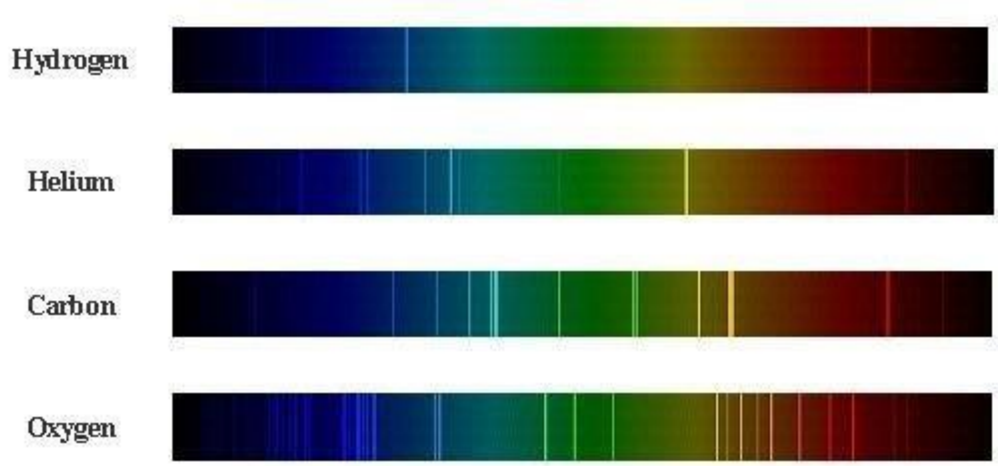
Spectroscopy is the use of the absorption, emission, or scattering of electromagnetic radiation by matter to qualitatively or quantitatively study the matter or to study physical processes.

EM Spectrum



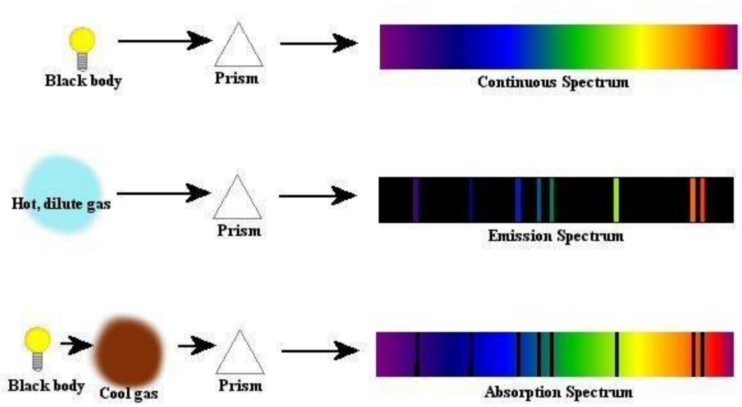
Electromagnetic spectrum is a wide range of electromagnetic radiation which carries radiation of different wavelength. Electromagnetic waves have an enormous range, and as a result it is very convenient to see where each of the different forms of radiations fits within the spectrum as a whole.

Atomic spectra



When atoms are excited they emit light of certain wavelengths which correspond to different colors. The emitted light can be observed as a series of colored lines with dark spaces in between; this series of colored lines is called a line or atomic spectra. Each element produces a unique set of spectral lines.

Emission spectra or line spectra



The spectrum of bright lines, bands, or continuous radiation characteristic of and determined by a specific emitting substance subjected to a specific kind of excitation is called as spectra. When radiation is emitted, lines are obtained, it is called as emission spectra.

Continuous spectra

The spectrum formed from white light contains all colors, or frequencies, and is known as a continuous spectrum.Continuous spectra are produced by all incandescent solids and liquids and by gases under high pressure.

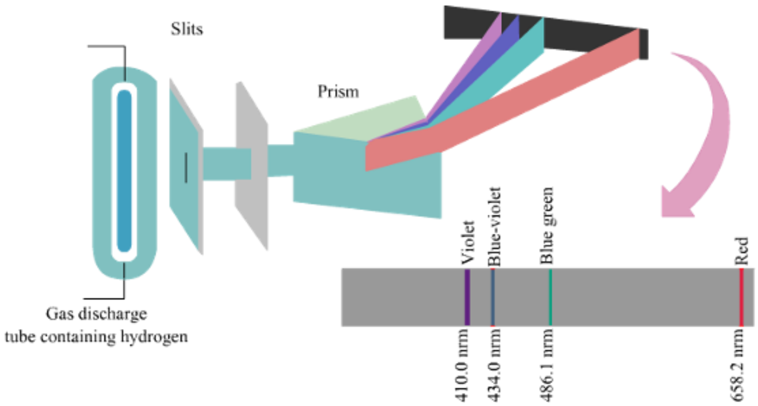
Absorption spectra

An absorption spectrum occurs when light passes through a cold, dilute gas and atoms in the gas absorbed at characteristic frequencies; since the re-emitted light is unlikely to be emitted in the same direction as the absorbed photon, this gives rise to dark lines (absence of light) in the spectrum.

Difference between emission and absoroption spectrum

When an atom or molecule excites, it absorbs a certain energy in the electromagnetic radiation; therefore, that wavelength will be absent in the recorded absorption spectrum.
When the species come back to the ground state from the excited state, the absorbed radiation is emitted, and it is recorded. This type of spectrum is called an emission spectrum.
In simple terms, absorption spectra records the wavelengths absorbed by the material, whereas emission spectra records wavelengths emitted by materials, which have been stimulated by energy before.
Compared to the continuous visible spectrum, both emission and absorption spectra are line spectra because they only contain certain wavelengths.
In an emission spectrum there will be only few colored bands in a dark back ground. But in an absorption spectrum there will be few dark bands within the continuous spectrum. The dark bands in the absorption spectrum and the colored bands in the emitted spectrum of the same element are similar.

Emission spectrum of hydrogen



When hydrogen gas at low pressure is taken in discharged tube and the light emitted on passing electric charge is examined with spectroscope, the spectrum obtained is called emission spectrum of hydrogen.

Bohr's Model of Atom

Back in 20th century, scientists made several attempts to explain the structure of atom. Although unsuccessful, Rutherfords model of atom played a key role in discovery of a much successful model which was given by Neil Bohr in 1913. The Rutherford model had a major drawback; it could not explain why electrons do not fall into the nucleus by taking a spiral path. It was in line with the electromagnetic theory which says "if a charged particle undergoes accelerated motion, then it must radiate energy (lose) continuously". Bohr proposed the Quantum Theory of Atom. He retained some key postulates of Rutherford and added some points using Quantum Physics. Hence, his model is also known as Rutherford-Bohr model.

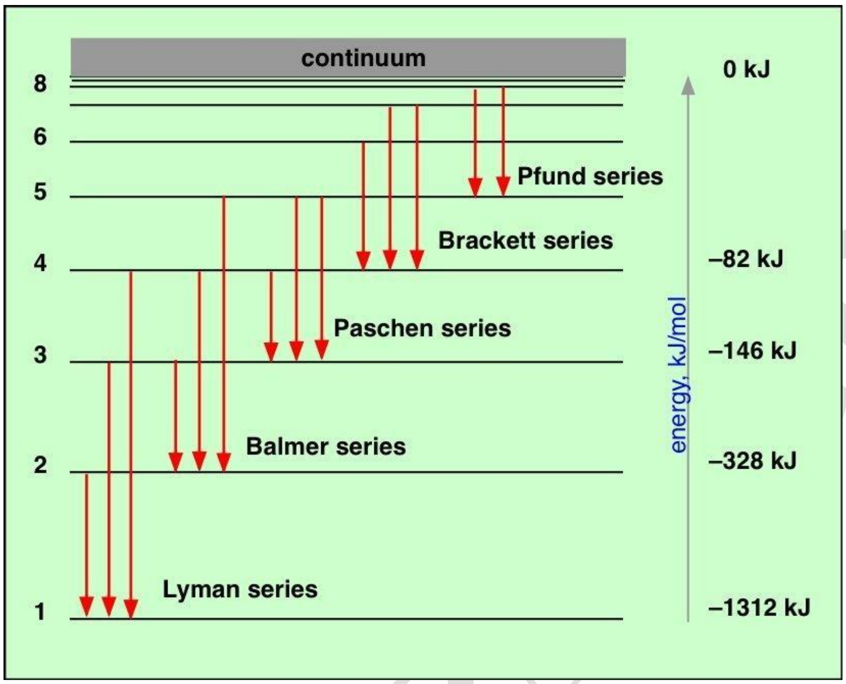
Quantization of electronic energy

Energy of each orbit is fixed. The electron can jump from one orbit to another by absorbing or emitting the same or more amount of energy than the energy of the orbit in which it is moving. One of the implications of these quantized energy states is that only certain photon energies are allowed when electrons jump down from higher levels to lower levels, producing the hydrogen spectrum.

Usefulness of Bohr's Model

The Bohr model of the atom is important because it better described the structure of these tiny particles we call atoms. Of particular importance is the idea that electrons, those tiny negative charges, move around the nucleus in orbitals or energy levels. This opened the door (busted it down, actually) to a much clearer understanding of chemistry and a host of electromagnetic phenomenon.

Hydrogen spectrum



Limitations of Bohr's model

It could not explain the line spectrum of multi electron atoms.
This model failed to explain the effect of magnetic field on the spectra of atoms (Zeeman effect).
The effect of electric field on the spectra could not be explained by Bohr's model (Stark effect).
The shapes of molecules arising out of directional bonding could not be explained.
The dual nature of electrons (both as wave and particle) and the path of motion of the electron in well defined orbits were not correct.

Bohr-Sommerfield model of atom

According to him, the stationary orbits in which electrons are revolving around the nucleus in the atom are not circular but elliptical in shape. It is due to the influence of the centrally located nucleus. The electron revolves in elliptical path with nucleus at one of its foci. So there will be a major and a minor axis of the path. He said that with the broadening of the orbit, the lengths of the two axis approach to equal value and ultimately become equal i.e. the path become circular. So we can say the circular path is just one special case elliptical path.
As electrons travel in elliptical path, it will have an angular momentum and this angular momentum must be quantized according to the quantum theory of radiations. Bohr gave that angular momentum as nh2πnh2πbut Sommerfeld used another integer k instead of n. k is an integer known as azimuthal quantum number. n used by Bohr and k used by Sommerfeld are related as:
n/k = length of major axis/length of minor axis
With increase in value of k, the path becomes more and more elliptical and eccentric. When k=n, the path becomes circular

Dual nature of matter

Matter can exist as a particle as well as a wave.

The wave-like nature of light explains most of its properties:
Reflection/refraction
Diffraction/interference
Doppler effect
This dualism to the nature of light is best demonstrated by the photoelectric effect, where a weak UV light produces a current flow (releases electrons) but a strong red light does not release electrons no matter how intense the red light.

Particle and Wave

Wave	Particle
A wave is described as a vibration or disturbance having a certain energy that can be either moving or stationary.	A particle is a physical entity which consists of a certain shape, physical dimensions and mass. It can either be moving or stationary. There is certainty in the position in space.
Every wave has a frequency associated with it.	Particles do not have a frequency associated with it

Characterisitcs of matter wave

They represent the resultant of group of waves
They represent, the wave associated with a particle if the constituents are particles and represent the waves associated with photons if it is an electromagnetic radiation.
The wavelength associated with the particles $\lambda = h/p$ where h is Planks constant, p is the momentum associated with the particle. If the de-Broglie wavelength associated with electromagnetic radiation λ is given by hc/E where c is the velocity of light and E is the energy associated with the photon.
The amplitude of these matter waves being very small and being the resultant of group of waves the amplitude determined of a de-Broglie wave only gives us the probability of occurrence of the constituent particle at a given position and at a given time.
The velocity associated with the electromagnetic radiation remains constant for all the wave lengths while the velocity of matter wave differs under different conditions associated with it.

Characteristics of EM waves

1. There are two fields of electromagnetic waves:

Electric field
Magnetic field
2. The angle between the electric and magnetic field is 90^o.
3. The electric and magnetic field is perpendicular to the direction of propagation
4. When EM waves travel, the energy is wasted while travelling from source to load.
5. The speed of electromagnetic waves is same as speed of light.

De broglie relation

De Broglie’s Equation

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

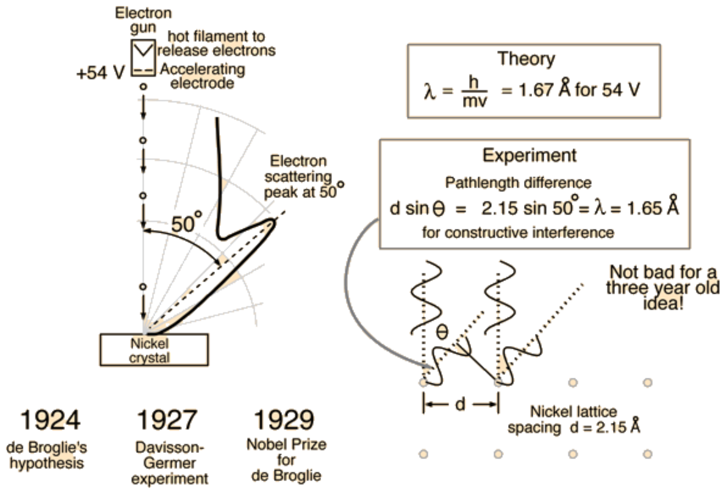
Where
λ = wavelength in meters
v = the velocity in meters/sec
m = the mass in kilograms
h = Plancks's constant in J/Hz

From the above formula de Broglie equation is given.The de Broglie equation relates a moving particle's wavelength with its momentum. The de Broglie wavelength is the wavelength, associated with a massive particle and is related to its momentum, p, through the Planck constant, h. In other words, you can say that matter also behaves like waves.

Significance of de Broglie wavelength

De Broglie equation says that every moving particle - microscopic or macroscopic - is associated with a wavelength. For microscopic objects, wave nature is observable. For larger objects, the wavelength is even smaller still, quickly becoming so small as to become unnoticeable.
The wave particle duality of light was a big mystery for scientist. The light produce energy which traverses through space just like as the ripples spreading across the surface of a still pond after being disturbed by a dropped rock, it proves the wave like nature of light.
While light can be considered as a steady stream of particles just like tiny droplets of water sprayed from a garden hose nozzle. There are various experiments which can be proves the wave nature of light. At the same time some experiments favors the particle nature.

Davisson and Germer's experiment



The first experimental proof of the wave nature of electron was demonstrated in 1927 by two American physicists C.J Davison and L.H Germer. The basis of their experiment was that since the wavelength of an electron is of the order of spacing of atoms of a crystal, a beam of electrons shows diffraction effects when incident on a crystal.

Thomson's experiment for the verification of wave character

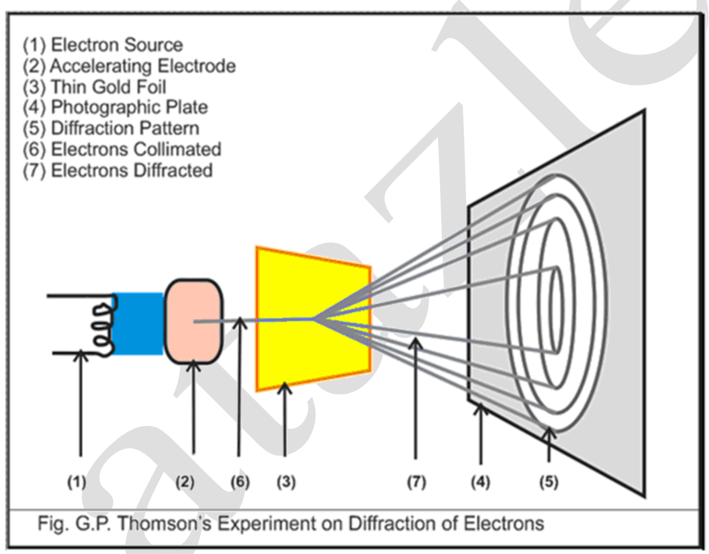


Fig. G.P. Thomson's Experiment on Diffraction of Electrons

After the experiments on diffraction of electrons by C. J. Davisson and L. H. Germer, G. P. Thomson, the son of J. J. Thomson, also replicated the experiment on electron diffraction in 1927. Electrons from an electron source were accelerated towards a positive electrode into which a small hole was drilled. The resulting narrow beam of electrons was directed towards a thin, rolled foil of gold. After passing through the hole in the gold foil, the electron beam was received on a photographic plate placed perpendicular to the direction of the beam. The diffraction pattern was in the form of continuous, concentric, alternate black and white rings as diffraction was due to the crystalline grains which were randomly oriented at all possible angles in the gold foil. Thus transmission of electrons through a thin foil of a poly crystalline material was studied.

Verification of particle character

1. The phenomenon of black body radiation and photoelectric effect prove the particle nature of radiation.
2. When an electron strikes a zinc sulphide screen, a spot of light known as scintillation is produced.

Heisenberg uncertainty principle

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

Δx = Uncertainty of Position
Δp = Uncertainty of Momentum

The above formula is used for Heisenberg's Uncertainty Principle.The position and momentum of a particle cannot be simultaneously measured with arbitrarily high precision. There is a minimum for the product of the uncertainties of these two measurements. There is likewise a minimum for the product of the uncertainties of the energy and time.

Significance of uncertainty principle

It is of significance only for microscopic particles. The energy of photon is insufficient to change the position and velocity of bigger bodies when it collides with them. In daily life, it has no significance.

Failure of Bohr's model

According to Bohr's model, the electrons are moving in fixed circular paths. The path can be defined only if the velocity and position of the electron are known exactly at the same time which is contradicted by Heisenberg uncertainty principle.

Need of quantum mechanics

The classical mechanics did not account for the dual nature of particles and Heisenberg's uncertainty principle. So the new branch has been put forward named quantum mechanics.

Schrodinger wave equation

Second derivative with respect to X

Shrodinger Wave Function

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0$$

Position

Energy

Potential Energy

The Schrodinger equation is the fundamental equation for describing quantum mechanical behavior. It is a partial differential equation that describes how the wave function of a physical system evolves over time. It is wave nature of electron in 3 dimensional space around nucleus.

The wavefunction for a given physical system contains the measurable information about the system. To obtain specific values for physical parameters, for example energy, you operate on the wavefunction with the quantum mechanical operator associated with that parameter. The operator associated with energy is the Hamiltonian, and the operation on the wavefunction is the Schrodinger equation. Solutions exist for the time-independent Schrodinger equation only for certain values of energy, and these values are called "eigenvalues*" of energy.

Quantum mechanical model

The quantum mechanical model describes the probable location of electrons in atoms by describing: Principal energy level, energy sublevel, orbital(in each sub-level), spin.

Electron cloud

It is used to describe where electrons are when they go around the nucleus of an atom. The electron cloud model is different from the older Bohr atomic model by Niel's Bohr.

Atomic orbital

An atomic orbital is a mathematical function that describes the wave-like behavior of either one electron or a pair of electrons in an atom. This function can be used to calculate the probability of finding any electron of an atom in any specific region around the atom's nucleus.

Orbit and Orbital

ORBIT	ORBITAL
It is well-defined circular path followed by electron around nucleus.	It is a region of space around the nucleus where the probability of finding an electron is maximum.
It represents two dimensional motion of electron around nucleus.	It represents three dimensional motion of electron around nucleus.
The maximum no. of electrons in an orbit is $2n^2$.	The maximum no. of electrons in an orbital is 2.
Orbit is circular in shape.	Orbitals have different shapes.

Features of quantum mechanical model

The energy of electrons in an atom is quantised (i.e., electrons can only have certain specific values of energy).
The existence of quantised electronic energy states is a direct result of the wave-like property of electrons.
The exact position and the exact velocity of an electron in an atom cannot be determined simultaneously (Heisenberg uncertainty principle).
An atomic orbital is represented by the wave function ψ, for an electron in an atom, and is associated with a certain amount of energy.
There can be many orbitals in an atom, but an orbital cannot contain more than two electrons.
The orbital wave function $\psi\psi$gives all the information about an electron.
$|\psi 2|$ is known as probability density, and from its value at different points within an atom, the probable region for finding an electron around the nucleus can be predicted.

Quantum numbers

A number that occurs in the theoretical expression for the value of some quantized property of a subatomic particle, atom, or molecule and can only have certain integral or half-integral values is called as quantum number, e.g., Principle quantum numbers, Azimuthal quantum numbers, spin quantum numbers.

Azimuthal quantum numbers

The orbital angular momentum quantum number l determines the shape of an orbital, and therefore the angular distribution. The number of angular nodes is equal to the value of the angular momentum quantum number l. Each value of l indicates a specific s, p, d, f sub-shell (each unique in shape.) The value of l is dependent on the principal quantum number n. Unlike n, the value of l can be zero. It can also be a positive integer, but it cannot be larger than one less than the principal quantum number (n-1): l=0,1,2,3,4,(n-1)

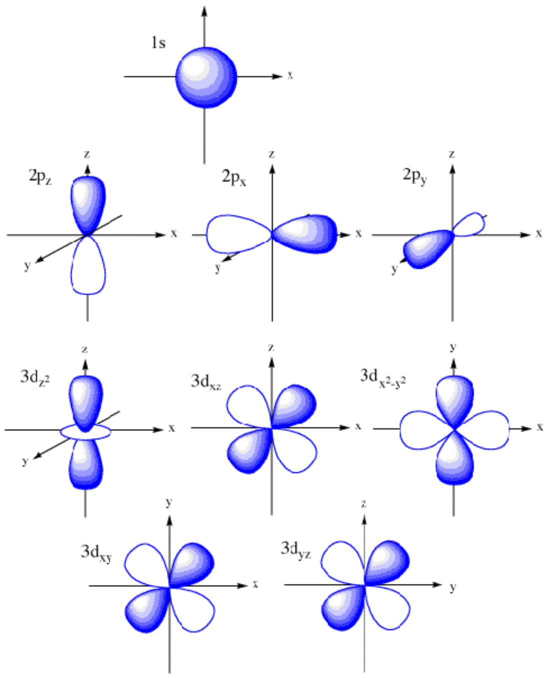
Orbitals

An atomic orbital is a mathematical function that describes the wave-like behavior of either one electron or a pair of electrons in an atom. This function can be used to calculate the probability of finding any electron of an atom in any specific region around the atom's nucleus. For example: 1s represent 1st orbit with s orbital.

Pauli exclusion principle

The Pauli exclusion principle is the quantum mechanical principle that states that two identical fermions (particles with half-integer spin) cannot occupy the same quantum state simultaneously. It means that orbitals are filled by singly first then they are paired.

Shape of atomic orbitals



s orbital-sphere
p orbital-dumbell
d orbital- double dumble
f orbital-complex

Shape of s orbital

s orbitals have a spherical shell shape and the faint dark blue circle represents in cross-section, the region of maximum electron density.
Only one s orbital exists for each principal quantum number denoted by 1s, 2s, 3s etc.

Shape of p-orbital

p orbitals are pairs of 'dumbbells' aligned along the x, y and z axis at 90^o to each other.
There are three p orbitals for each principal quantum number from 2 onwards denoted by 2p, 3p and 4p etc.

e.g. 2p can be composed of 2px, 2py and 2pz if all three orbitals for a particular principal quantum number are occupied.
If a p subshell is full it holds a maximum of 3 x 2 = 6 electrons.
There is no 1p because quantum rules do not allow this

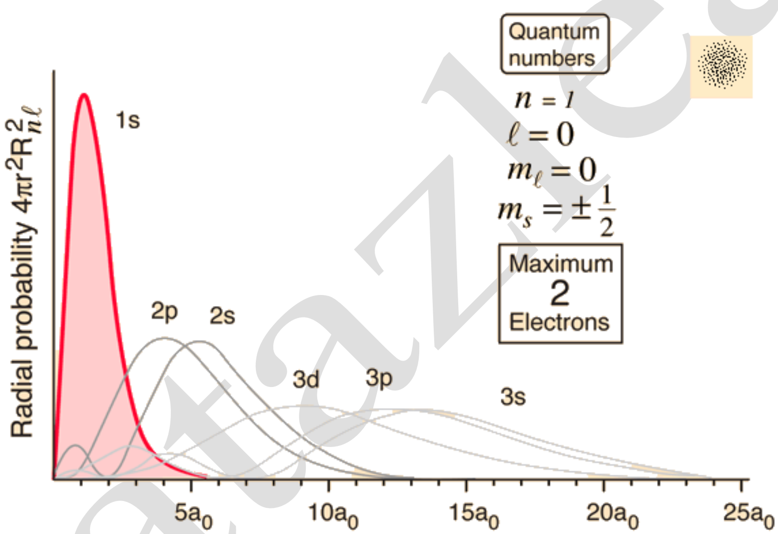
Nodal surface

A nodal surface is a region of space in which the probability of finding an electron is zero. Nodal spheres are found within 2s, 3s, 3p, 4p 4d, 5d orbitals. Nodal planes are found within any p,d.f orbital.

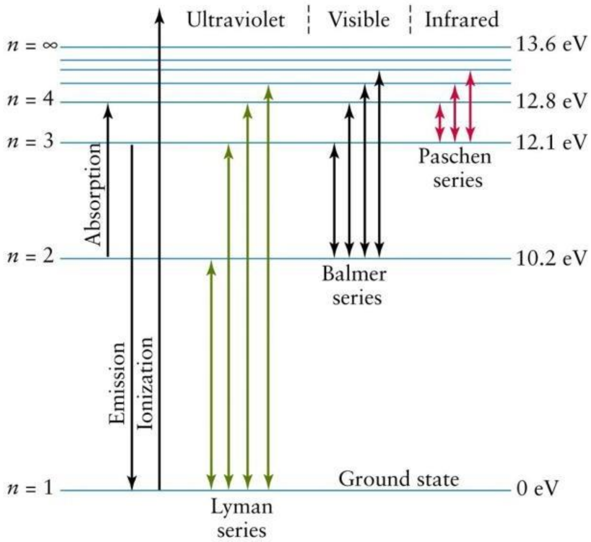
Boundary surface diagrams

Boundary surface diagram is a good diagrammatical representation of shapes of atomic orbitals. It is resultant of the solution of Schrodinger wave equation. As we know that the exact position and momentum of an electron cannot be determined (according to Heisenberg uncertainty principle), so we calculate probability density of finding an electron in a particular region. Boundary surface diagram is a boundary surface or a contour surface drawn in a space for an orbital on which the value of probability density |ψ||ψ| is constant. The boundary surface diagram of constant probability density is considered as a good and acceptable approximation of shape of orbital if the boundary surface encloses the region or volume with probability density of more than 90%. This means that the boundary surface enclosing a constant probability density of lets say 50% wont be considered good.

Plots of radial probability



Energy level diagrams of hydrogen atom



Difference of energy in the subshell of multi-electron atoms

For an atom that contains only one electron, there is no difference between the energies of the different sub shells within a shell. The 3*s*, 3*p*, and 3*d* orbitals, for example, have the same energy in a hydrogen atom. The Bohr model, which specified the energies of orbits in terms of nothing more than the distance between the electron and the nucleus, therefore works for this atom.
The hydrogen atom is unusual, however. As soon as an atom contains more than one electron, the different sub shells no longer have the same energy. Within a given shell,the *s* orbitals always have the lowest energy. The energy of the sub shells gradually becomes larger as the value of the angular quantum number becomes larger. Relative energies:s<p<d<f
Two factors control the energy of the orbital:size of the orbital and its shape.

Process of filling of electrons

When an atom or ion receives electrons into its orbitals, the orbitals and shells fill up in a particular manner. The rules of filling of electrons are: Aufbau's rule, Hund's rule, Pauli's exclusive principle, orbital order

Aufbau Principle

Orbitals with the lowest principal quantum number () have the lowest energy and will fill up first. Within a shell, there may be several orbitals with the same principal quantum number. In that case, more specific rules must be applied. For example, the three p orbitals of a given shell all occur at the same energy level. So, how are they filled up? ans: all the three p orbitals have same energy so while filling the p orbitals we can fill any one of the Px, Py or Pz first. it is a convention that we chose to fill Px first ,then Py and then Pz for our simplicity. Hence you can opt for filling these three orbitals from right to left also.

Hund's rule of maximum multiplicity

According to Hund's rule, orbitals of the same energy are each filled with one electron before filling any with a second. Also, these first electrons have the same spin. This rule is sometimes called the "bus seating rule". As people load onto a bus, each person takes his own seat, sitting alone. Only after all the seats have been filled will people start doubling up.

Exchange energy

Exchange energy is the energy released when two or more electrons with the same spin exchange their positions in the degenerate orbitals of a sub-shell. Let's assume an atom in which there are 5 unpaired electrons (i.e one unpaired electron in each one) in its n d-orbital.

Charged particles

The charged particles are the particles which carries positive or negative charge on them. Ions could be positively or negatively charged, based on either they lose or gain the electrons in the outermost shell of their atom.

Electrical nature of matter

Matter is electrically neutral. It contains the equal number of protons and electrons that make the matter neutral. If there is a dis-balance in any one of them then the matter is positively or negatively charged depending on whether proton or electrons are more in number.

Discovery of electron by J.J. Thomson

In 1878 William Crooks carried out discharge tube experiments and discovered new radiations and called them cathode rays. Since these rays travel from the cathode towards anode. Later, J.J Thomson studied the characteristics of cathode rays and concluded that cathode rays are negatively charged particles, now called electrons. The name electron was given by Johnson Stoney.

Properties of Cathode rays

1. Cathode rays travel in straight lines. That is why, cathode rays cast shadow of any solid object placed in their path. The path cathode rays travel is not affected by the position of the anode.
2. Cathode rays consist of matter particles, and posses energy by the virtue of its mass and velocity. Cathode rays set a paddle wheel into motion when it is placed in the path of these rays one the bladder of the paddle wheel.
3. Cathode rays consist of negatively charged particles. When cathode rays are subjected to an electrical field, these get deflected towards the positively charge plate(Anode).
4. Cathode rays heat the object only which they fall. The cathode ray particles possess kinetic energy. When these particles strike an object, a part of the kinetic energy is transferred to the object. The causes a rise in the temperature of the object.
5. Cathode rays cause green fluorescence on glass surface, i.e., the glass surface only which the cathode rays strike show a colored shine.
6. Cathode rays can penetrate through thin metallic sheets.
7. Cathode rays ionize the gases through which they travel.

Electron and its properties

Electron is the negative part of the matter. It is negatively charged. The properties of electrons are:

They are produced by the negative electrode, or cathode, in an evacuated tube, and travel towards the anode.
They travel in straight lines and cast sharp shadows.
They have energy and can do work.
They are deflected by electric and magnetic fields and have a negative charge.

Discovery of electrons by William Crookes

William Crookes in 1879, studied the conduction of electricity through a gases at low pressure. For this purpose, he took a discharge tube which is a long glass tube, about 60 cm long, sealed at both the ends and fitted with metal electrodes. It has a side tube fitted with a stop cock which can be connected to a vacuum pump to reduce the pressure of the gas inside to any desired value. These tubes are also now called as Crookes tube.

e/m ratio by J.J Thompson

In 1897, the cathode ray tube or CRT, which is now a part of most TV sets, was the last word in advanced laboratory instrumentation and TV was still 40 to 50 years in the future. At Cambridge University in England, J.J Thomson studied the rays emanating from the cathode of the CRT. Thomson measured the ratio of charge to mass (e/m) of these corpuscles of which the rays were composed. We now call them electrons. Well do his experiment, with a somewhat modified apparatus. Main parts of the apparatus electron gun consists of filament, cathode and anode. He setup the experiment in the same way as William Crookes. When the rays got emitted he measured the e/m ratio by use of magnetic and electric fields.

Millikan Oil's drop experiment

- Millikan's oil drop experiment measured the charge of an electron. Before this experiment, existence of subatomic particles, was not universally accepted. Millikan's apparatus contained an electric field created between a parallel pair of metal plates, which were held apart by insulating material. Electrically charged oil droplets entered the electric field and were balanced between two plates by altering the field.
- When the charged drops fell at a constant rate, the gravitational and electric forces on it were equal. Therefore, the charge on the oil drop was calculated using formula. Millikan found that the charge of a single electron was 1.6×10^{-19}1.6×10−19 C.

Discovery of proton by Goldstein

In 1886, E. Goldstein carried out discharge tube experiments and discovered new radiations and called them canal rays. These rays were made up of positively charged particles and led to the discovery of proton.

Properties of anode rays

Some of the characteristic properties of anode rays are:
Anode rays consist of material particles.
Anode rays are deflected by electric field towards negatively charged plate. This indicates that they are positively charged.

The charge to mass ratio of the particles in the anode rays was determined by W. Wien by using Thomsons technique. Charge to mass ratio of the particles in the anode rays depends upon nature of the gas taken in the discharged tube.
They travel in straight line.

Canal Rays

A canal ray (also positive ray or anode ray) is a beam of positive ions that is created by certain types of gas dicharge tubes.

Define proton and explain its properties

A proton is a subatomic particle , symbol p or p+, with a positive electric charge of +1 and mass slightly less than that of a neutron present in nucleus of every atom. The number of protons in the nucleus is the defining property of an element, and is referred to as the atomic number (represented by the symbol Z).
properties :

Particle	Charge	Mass (g)
Proton	+1	1.6727 x 10-24

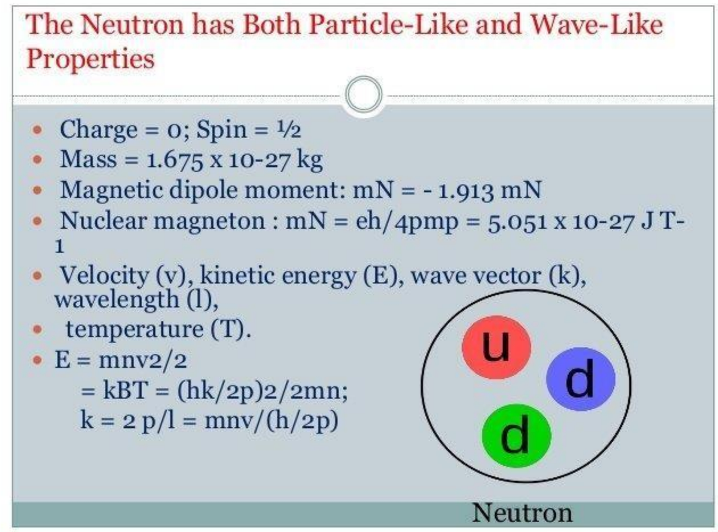
Discovery of neutrons by J. Chadwick

It was found that helium has two protons and two electrons, however, its mass was found to be four times that of hydrogen. Similarly, the masses of some other elements were also found to be double or more than double the number of protons. This problem was solved on the discovery of another particle neutron by James Chadwick In 1932 by bombarding beryllium with alpha particles. Neutron is a neutral particle with a mass equal to that of a proton and is present in the nucleus along with a proton.

Postulates of discovery of neutrons

The particle present in nucleus along with proton is neutral made from close combination of proton and electron.
The particle has no charge and mass almost equal to the mass of proton.

Properties of neutrons



Radioactivity

Radioactive decay, also known as nuclear decay or radioactivity, is the process by which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays and conversion electrons. A material that spontaneously emits such radiation is considered radioactive.

Alpha, Beta and Gamma particles

Characteristic of Alpha, Beta & Gamma Rays			
Characteristic	Alpha	Beta	Gamma
Emission of	2 P+2N	1 electron – High K.E.	Photon- very high frequency e-m rad.
Changes from	Uranium to Plutonium	Radium to Polonium	No change
Charge C	+2	-1	0
Mass kg	4	1/1850	0
Speed km/s	15000	3x10^9	300,000 km/s
% of speed of light	5%	Close to 100%	100%
K.E	5 MeV	5 KeV to 1 MeV	100 keV to < 10MeV
Penetration Power	Low – Large mass & charge-can be stopped by a thin sheet of paper	Moderate – medium mass and charge- can be stopped by a few mm thick metal	Very High – no mass, no charge - can be stopped only by a very thick cement or steel block
Ionization power	Very High – large charge	Moderate – low charge	Low – no charge

Table – Radiation Ray characteristics

Distribution of electrons

Electrons fill orbitals in a way to minimize the energy of the atom. Therefore, the electrons in an atom fill the principal energy levels in order of increasing energy (the electrons are getting farther from the nucleus).
The order of levels filled looks like this:
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, and 7p
One way to remember this pattern, probably the easiest, is to refer to the periodic table and remember where each orbital block falls to logically deduce this pattern.

Table of configuration of first 18 elements

Composition of the atoms of the first eighteen elements :-

Name of element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution Of Electrons K L M N	Valency
Hydrogen	H	1	1	-	1	1 - - -	1
Helium	He	2	2	2	2	2 - - -	0
Lithium	Li	3	3	4	3	2 1 - -	1
Beryllium	Be	4	4	5	4	2 2 - -	2
Boron	B	5	5	6	5	2 3 - -	3
Carbon	C	6	6	6	6	2 4 - -	4
Nitrogen	N	7	7	7	7	2 5 - -	3
Oxygen	O	8	8	8	8	2 6 - -	2
Fluorine	F	9	9	10	9	2 7 - -	1
Neon	Ne	10	10	10	10	2 8 - -	0
Sodium	Na	11	11	12	11	2 8 1 -	1
Magnesium	Mg	12	12	12	12	2 8 2 -	2
Aluminium	Al	13	13	14	13	2 8 3 -	3
Silicon	Si	14	14	14	14	2 8 4 -	4
Phosphorus	P	15	15	16	15	2 8 5 -	3,5
Sulphur	S	16	16	16	16	2 8 6 -	2
Chlorine	Cl	17	17	18	17	2 8 7 -	1
Argon	Ar	18	18	22	18	2 8 8 -	0

Calculate valency of an atom

The valency of hydrogen and all metals is positive. The valency of non- metals is negative. The valency of a molecule is zero.
Valency is calculated by calculating number of electrons present in outermost orbitals of atom of element.
For example : Valency of Nitrogen is 3 because outermost orbital contain 3 electron.

Chart of arrangement of atoms

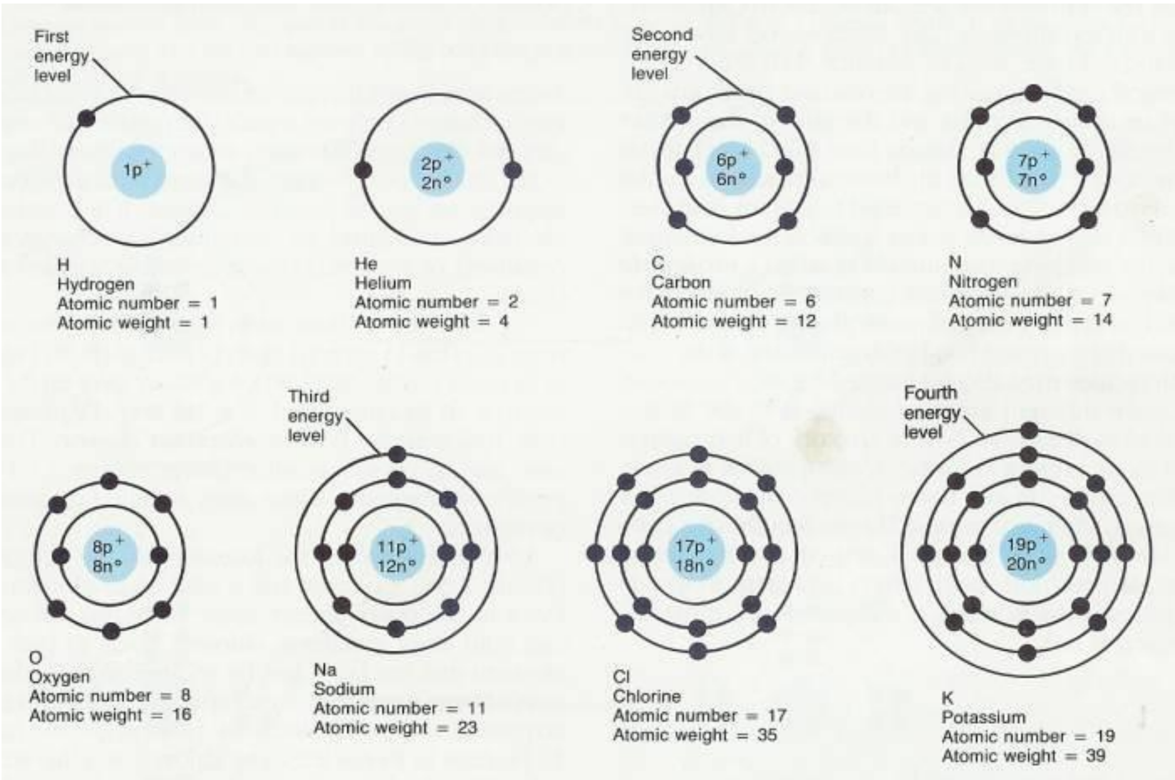
Name of Elements	Symbol	Atomic Number	Number of Electrons	Number of Protons	No. of Neutrons	Atomic Mass	Electronic Configuration			
							K	L	M	N
Hydrogen	H	1	1	1	-	1	1	-	-	-
Helium	He	2	2	2	2	4	2	-	-	-
Lithium	Li	3	3	3	4	7	2	1	-	-
Beryllium	Be	4	4	4	5	9	2	2	-	-
Boron	B	5	5	5	6	11	2	3	-	-
Carbon	C	6	6	6	6	12	2	4	-	-
Nitrogen	N	7	7	7	7	14	2	5	-	-
Oxygen	O	8	8	8	8	16	2	6	-	-
Heroine	F	9	9	9	10	19	2	7	-	-
Neon	Ne	10	10	10	10	20	2	8	-	-
Sodium	Na	11	11	11	12	23	2	8	1	-
Magnesium	Mg	12	12	12	12	24	2	8	2	-
Aluminum	Al	13	13	13	14	27	2	8	3	-
Silicon	Si	14	14	14	14	28	2	8	4	-
Phosphorus	P	15	15	15	16	31	2	8	5	-
Sulphur	S	16	16	16	16	32	2	8	6	-
Chlorine	Cl	17	17	17	18	35.5	2	8	7	-
Argon	Ar	18	18	18	22	40	2	8	8	-
Potassium	K	19	19	19	20	39	2	8	8	1
Calcium	Ca	20	20	20	20	40	2	8	8	2

The electrons are arranged in the following manner according to diagram.

Factors governs the distribution of electrons

1.Heisenberg's uncertainty principle.
2.Aufbau's principle.
3.Pauli's exclusion theory.

Atomic diagrams of elements



Stable electronic configuration of noble gases

Noble gas configuration is the term given to the octet electronic configuration of noble gases. The basis of all chemical reactions is the tendency of chemical elements to acquire stability. For some main group elements, chemical bond formation often results in a complete electronic configuration resembling a noble gas.

Every system has the tendency to acquire the state of stability or a state of minimum energy and so chemical elements take part in chemical reactions to acquire a stable electronic configuration similar to that of its nearest noble gas.

Noble gases contain even number of electron in orbital or they contain completely filled atomic orbitals hence they do not take part in chemical reactions and their electronic configuration is stable.

Formation of electrovalent compounds

Chemical bond formed between two atoms due to transfer of electron(s) from one atom to the other atom is called "Ionic bond" or electrovalent bond. Electrovalent compounds are formed by the transfer of electrons from one to another ion resulting in the completion of octet.

Formation of covalent compounds

Covalent compounds are formed by sharing of electrons. The sharing results in completion of octet so the species become stable. e.g Oxygen has six electrons in the outermost shell. It needs two electrons to complete the octet. Oxygen shares two electrons with another oxygen atom to complete the octet.

Formation of ions

Ions are formed when atoms lose or gain electrons in order to fulfill the octet rule and have full outer valence electron shells. When they lose electrons, they become positively charged and are named cations. When they gain electrons, they are negatively charged and are named anions.

Thomson's model of an atom

J.J. Thomson was the first to put forward a model to explain the structure of an atom. Thomson's atomic model is also called water melon model or Christmas pudding model. He compared the electrons with the raisins in the spherical Christmas pudding and to seeds in a watermelon. In which he describe the resin as electrons and spherical body as central body in which electrons revolves.

Postulates of Thomson's atomic model

An atom consists of a positively charged sphere, with electrons set within the sphere.
An atom is electrically neutral as the positive and negative charges within it are equal.

Limitations of Thompson's model

It could not explain the result of the scattering experiment performed by Rutherford
It did not have any experiment evidence in its support

Rutherford's model of an atom

To study the structure of atom, Rutherford performed a thin gold foil scattering experiment. For his experiments Rutherford used a gold foil. He made a narrow beam of alpha particles to fall on the gold foil. Observations made from the alpha ray scattering experiment: Most of the alpha particles passed straight through the gold foil without getting deflected, a small fraction of the alpha particles were deflected through small angles, a few alpha particles bounced back.

Postulates of Rutherford's atomic model

Postulates of Rutherford's nuclear model:
  Positive charge is concentrated in the center of the atom, called nucleus.
  Electrons revolve around the nucleus in circular paths called orbits.
  The nucleus is much smaller in size than the atom.