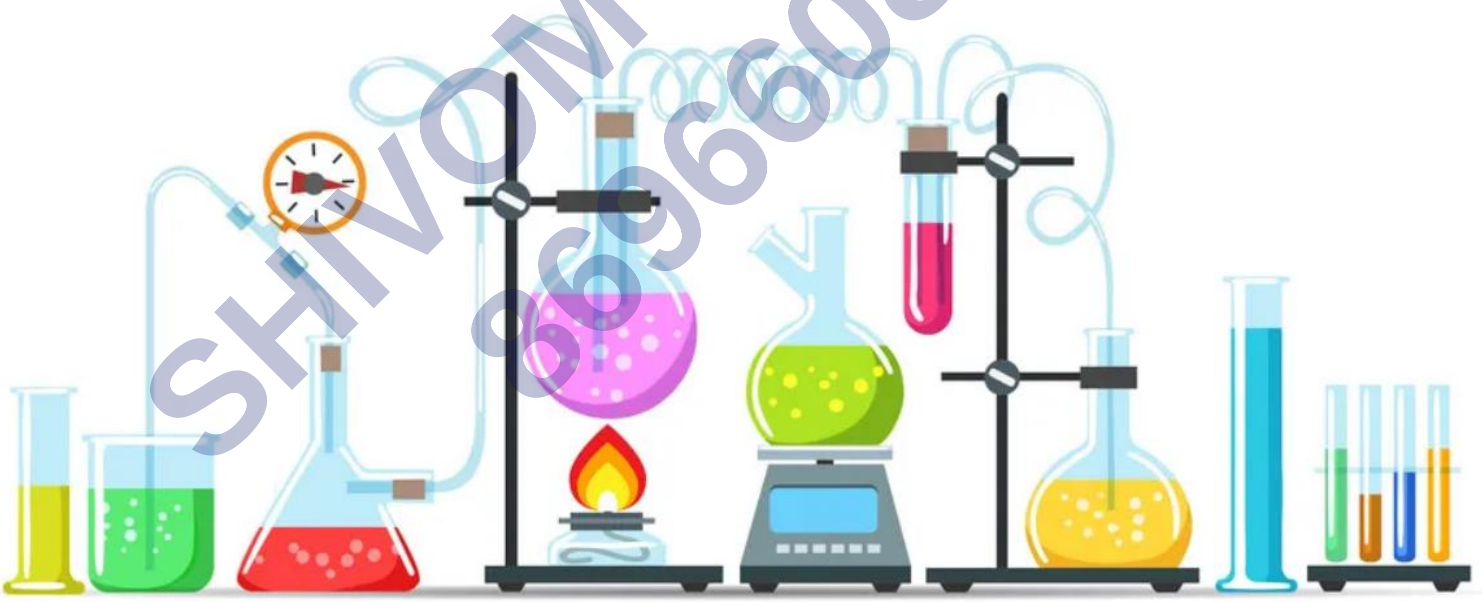
CHEMISTRY

CHAPTER 2: STRUCTURE OF ATOM



STRUCTURE OF ATOM

Introduction:

The word "atom" has been derived from the Greek word 'atoms’ which mans '**indivisible**’. These early ideas were mere speculation and there was no way to test them experimentally.

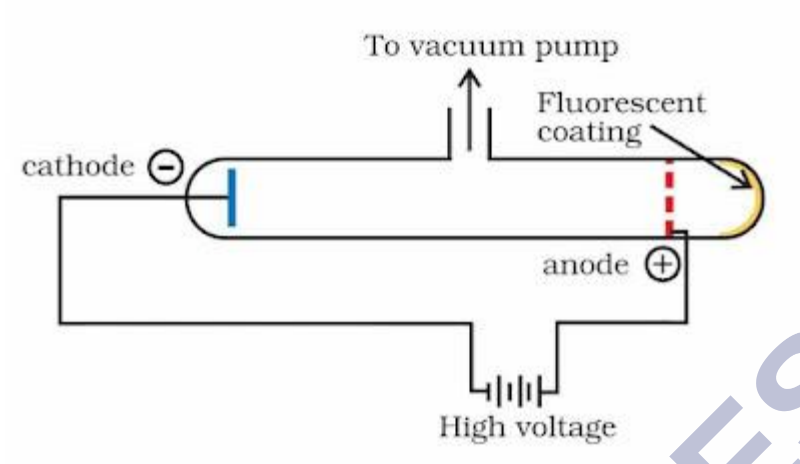
Atomic Structure:

Atom is made up of smaller units like proton, neutron and electron. Some other particles like positron, neutrino, antineutrino, π-meson, μ-meson, k meson etc are also present which are very short lived.

Particle	Mass	Charge	Special Remark
Electron	9.1×10^{-31} kg	-1.6×10^{-19} C	Discovered by J.J. Thomson
Proton	1.67×10^{-27} kg	$+1.6 \times 10^{-19}$ C	Discovered by Gold Stein
Neutron	1.67×10^{-27} kg		Discovered by Chadwick
Positron		$+1.6 \times 10^{-19}$	Anderson
π meson	π° - 264 Me π^{+} - 273 Me π^{-} 273 Me		Yukawa

Discovery of Electron

In 1879, **William Crooks** studied the conduction of electricity through gases at low pressure. He performed the experiment in a discharge tube which is a cylindrical hard glass tube about 60 cm in length. It is sealed at both the ends and fitted with two metal electrodes. The electrical discharge through the gases could be observed only at very low pressures and at very high voltages.



J.J. Thomson took a discharge tube and applied a voltage of a 10000 volt potential difference across it at a pressure of 10–2 mm of Hg. He found some glowing behind anode. It means some invisible rays produced at cathode strike behind anode and produce fluorescence. He named them cathode rays.

Properties of Cathode Rays

i. These rays have mechanical energy and travel in straight line.

ii. These rays are deflected towards positive plate of electric field. It means these are made up of negatively charged particle called **electron**.

iii. Colour observed is independent from nature of gas.

iv. Mulliken determined the charge on electron which is 1.602×10^{-19}C.

v. Specific charge on electron is calculated by J.J. Thomson.

Charge to mass ratio

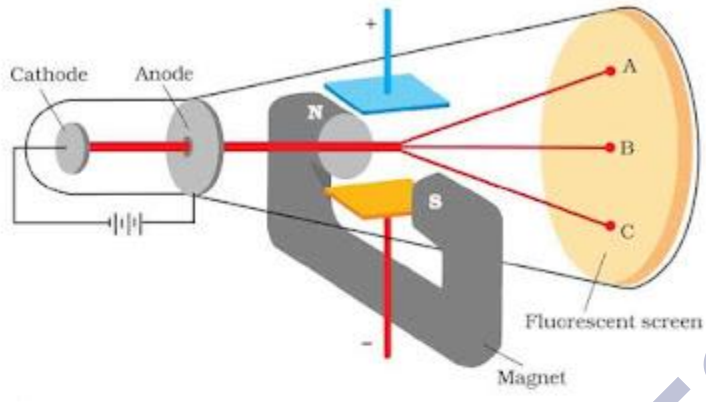
J.J. Thomson for the first time experimentally determined charge/mass ratio called e/m ratio for the electrons. For this, he subjected the beam of electrons released in the discharge tube as cathode rays to influence the electric and magnetic fields. These were acting perpendicular to one another as well as to the path followed by **electrons**.

According to Thomson, the amount of deviation of the particles from their path in presence of electrical and magnetic field depends on,

1. Magnitude of the negative charge on particle

2. Mass of particle

3. Strength of magnetic field



When electric field is applied, deviation from path takes place. If only electric field is applied, cathode rays strike at A. If only magnetic field is applied, cathode rays strike at C. In absence of any field, cathode rays strike at B.

By carrying out accurate measurements on the amount of deflections observed by the electrons on the electric field strength or magnetic field strength, Thomson was able to determine the value of $e/m_e = 1.758820 \times 10^{11}$ C kg^{-1}

where me = Mass of the electron in kg

e = magnitude of charge on the electron in coulomb (C).

Discovery of anode rays

In 1886, Goldstein modified the discharge tube by using a perforated cathode. On reducing the pressure, he observed a new type of luminous rays passing through the holes or perforations of the cathode and moving in a direction opposite to the cathode rays. These rays were named as positive rays or anode rays or as canal rays. Anode rays are not emitted from the anode but from a space between anode and cathode.

Properties of anode rays

1. These rays deflect towards negative plate of applied electric field. It means these are made up of positively charged particle.
2. Property of anode rays depends on nature of gas.
3. These rays travel in straight line and have mechanical energy.

Discovery of Neutron

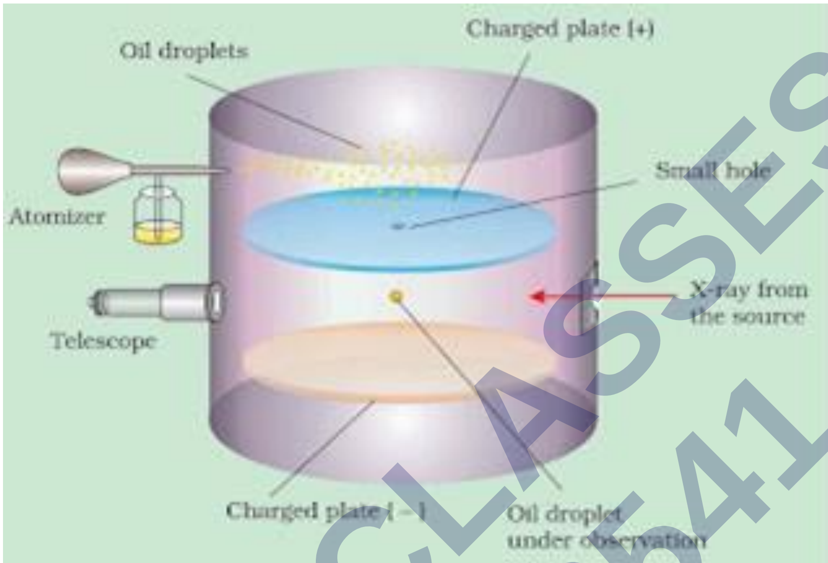
Chadwick in 1932 found the evidence for the production of neutron in given reaction.

$$_{4}Be^{9} + _{2}He^{4} \longrightarrow _{6}C^{12} + _{0}n^{1}$$

Neutron is chargeless particle and have mass equal to proton.

Millikan's Oil Drop Experiment

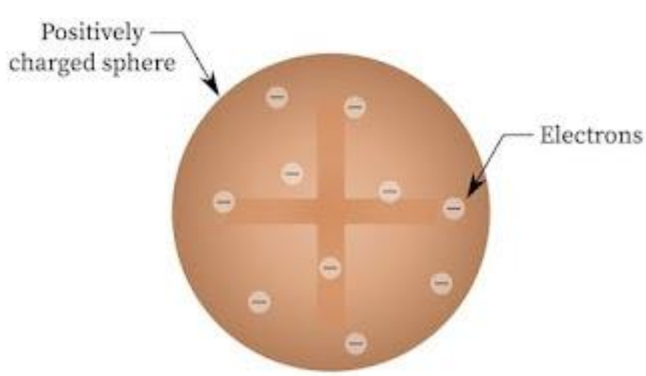
In this experiment, some fine oil droplets were allowed to enter through a tiny hole into the upper plate of electrical condenser. These oil droplets were produced by atomiser. The air in the chamber was subjected to the ionization by X-rays. The electrons produced by the ionization of air attach themselves to the oil drops.



Thus oil droplets acquire negative charge. When sufficient amount of electric field is applied, the motion of the droplets can be accelerated, retarded or made stationary. Millikan observed that the smallest charge found on them was -1.6×10^{-19} coulomb and the magnitude of electrical charge, q on the droplets is always an integral multiple of the electrical charge 'e' i.e., $q = ne$

Thomson's Model of Atom

J.J. Thomson in 1898, proposed a model of atom which looked more or less like plum pudding or raisin pudding. He assumed atom to be a spherical body in which electrons are unevenly distributed in a sphere having positive charge which balance the electron's charge. It is called Plum pudding model.

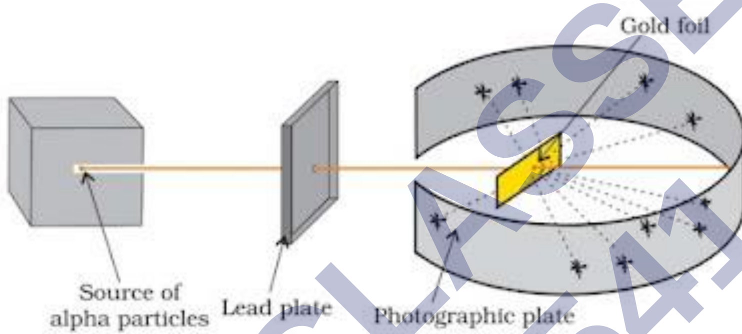


Important Feature of This Model: The mass of the atom is assumed to be uniformly distributed over whole atom.

Failure: This model was able to explain the overall neutrality of the atom, it could not satisfactorily, explain the results of scattering experiments carried out by Rutherford in 1911.

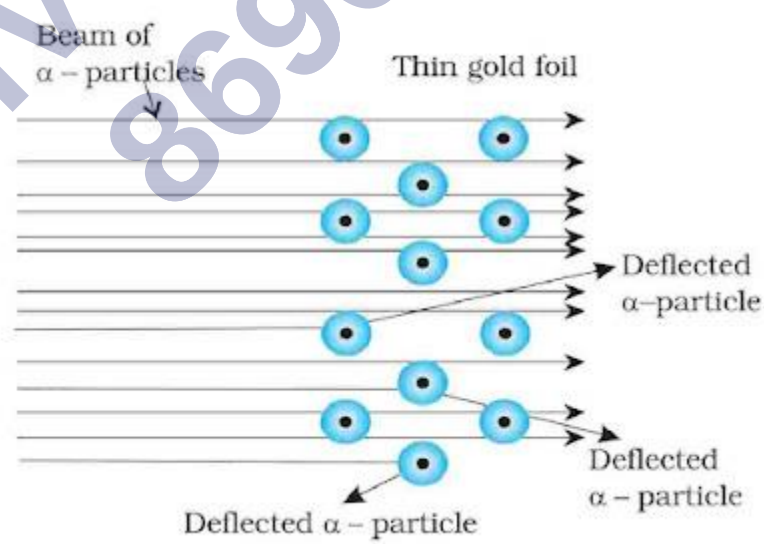
Rutherford's Model

Rutherford in 1911, performed some scattering experiments in which he bombarded thin foils of metals like gold, silver, platinum or copper with a beam of fast moving a-particles. The thin gold foil had a circular fluorescent zinc sulphide screen around it. Whenever a-particles struck the screen, a tiny flash of light was produced at that point.



From these experiments, he made the following observations:

1. Most of the α-particles pass without any deviation.
2. Few particles deviate with small angle.
3. Rare particles retrace its path or show deflection greater than 90°.



On the basis of these observation, he proposed a model.

1. Atom is of spherical shape having size of order 10–10 meters.

2. Whole mass is concentrated in centre called nucleus having size of order 10–15 meters.
3. Electron revolves around the nucleus in circular path like planets revolve around sun.

Limitation: This model could not explain stability of atom. According to Maxwell's classic theory, an accelerated charged particle liberates energy. So, during revolution, it must radiate energy and by following the spiral path it should comes on nucleus.

Atomic number

It is equal to the number of protons present in the nucleus of an atom. Atomic number is designated by the letter 'Z'. In case of neutral atom atomic number is equal to the number of protons and even equal to the number of electrons in atom.

Z = Number of protons (p) = Number of electrons (e)

Mass number

It is equal to the sum of the positively charged protons (p) and electrically neutral neutrons (n). Mass number of an atom is designated by the letter 'A'.

Mass number (A) = Number of protons (p or Z) + Number of neutrons (n)

Note: The atom of an element X having mass number (A) and atomic number (Z) may be represented by a symbol $_{Z}X^{A}$.

Isotopes

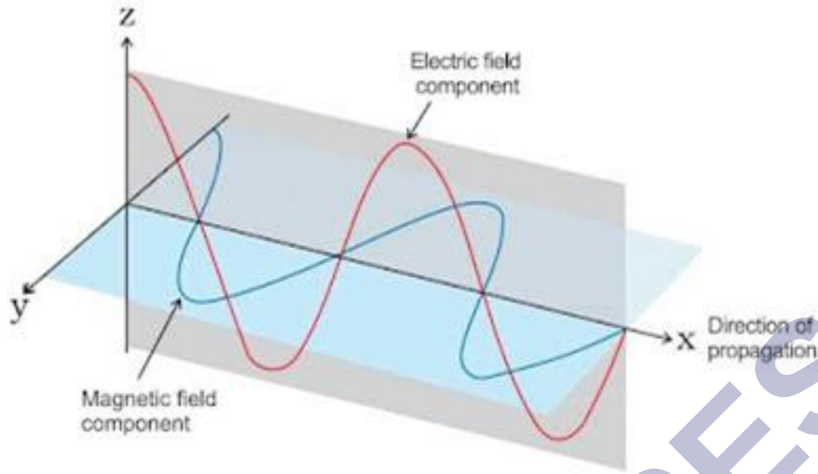
Atoms with identical atomic number but different atomic mass number are known as Isotopes. Isotopes of Hydrogen $_{1}H^{1}$, $_{1}H^{2}$ and $_{1}H^{3}$

Isobars

Isobars are the atom with the same mass number but different atomic number, for example $_{6}C^{14}$ and $_{7}N^{14}$

Electromagnetic Waves Theory

This theory was put forward by James Clark Maxwell in 1864. Electromagnetic Waves are the waves which are produced by varying electric field and magnetic field which are perpendicular to each other in the direction perpendicular to both of them.



The main points of this theory are as follows:

1. The energy is emitted from any source continuously in the form of radiations and is called the radiant energy.
2. The radiations consist of electric and magnetic fields oscillating perpendicular to each other and both perpendicular to the direction of propagation of the radiation.
3. The radiations possess wave character and travel with the velocity of light 3×10^8 m/sec.
4. These waves do not require any material medium for propagation. For example, rays from the sun reach us through space which is a non-material medium.

Characteristics of a Wave

Wavelength (λ): It is the distance between two consecutive crests or troughs and is denoted by λ.

Frequency (v): It is the number of waves passing through a given point in one second. The unit frequency is hertz or cycle per second.

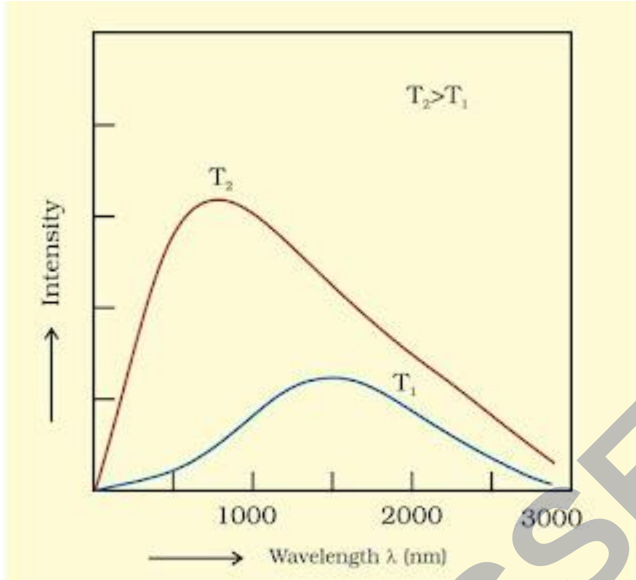
Wave number: It is the number of waves in a unit cycle. wave number =1λ=1λ

Velocity: Velocity of a wave is defined as the linear distance travelled by the wave in one second. It is represented by c and is expressed in m/sec.

Amplitude: Amplitude of a wave is the height of the crest or the depth of the through. It is represented by V and is expressed in the units of length.

Black Body Radiations

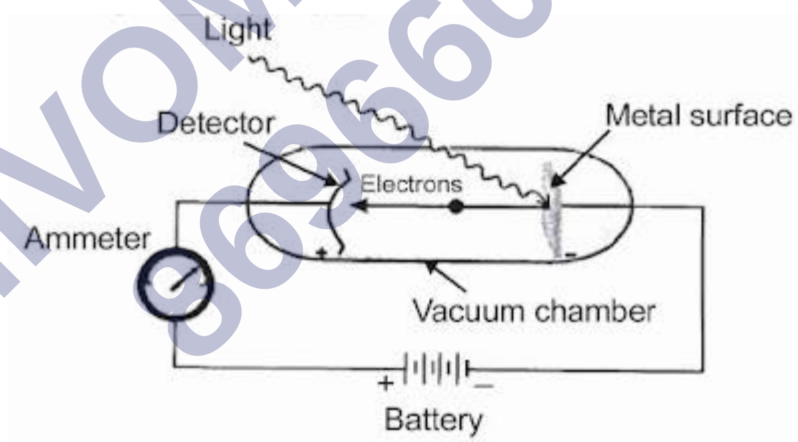
Black-body is an ideal body which emits and absorbs radiations of all frequencies. The radiation emitted by these bodies is called **black-body radiation**.



At a given temperature, the intensity and frequency of the emitted radiation depends is temperature. At a given temperature, the intensity of radiation emitted increases with decrease of wavelength.

Photoelectric Effect

When light of a suitable frequency is allowed to incident on a metal, ejection of electrons take place. This phenomenon is known as photo electric effect.



Observations in Photoelectric Effect

1. Only photons of light of certain minimum frequency called threshold frequency (v_0) can cause the photoelectric effect. The value of v_0 is different for different metals.
2. The kinetic energy of the electrons which are emitted is directly proportional to the frequency of the striking photons and is quite independent of their intensity.
3. The number of electrons that are ejected per second from the metal surface depends upon the intensity of the striking photons or radiations and not upon their frequency.

Explanation of Photoelectric Effect

Einstein in (1905) was able to give an explanation of the different points of the photoelectric effect using Planck's quantum theory as under:

1. Photoelectrons are ejected only when the incident light has a certain minimum frequency (threshold frequency v_0).
2. If the frequency of the incident light (v) is more than the threshold frequency (v_0), the excess energy ($hv - hv_0$) is imparted to the electron as kinetic energy.
3. On increasing the intensity of light, more electrons are ejected but the energies of the electrons are not altered.

   K.E. of the ejected electron.

   $\frac{1}{2}mv^2 = hv - hv_0$

Planck's Theory

According to this theory, energy cannot be absorbed or released continuously but it is emitted or released in the form of small packets called quanta. In case of light this quanta is known as photon. This photon travels with speed of light. Energy of the photon is directly proportional to frequency.

$$E \propto \nu$$
$$E = h\nu$$

h is ***Planck's constant***, value is 6.62×10^{-34} Js

Bohr's Model

1. Niels Bohr in 1913, proposed a new model of atom on the basis of Planck's Quantum Theory. The main points of this model are as follows:
2. Atom is of spherical shape having size (of order 10^{-10} metre).
3. Whole mass is concentrated in centre called nucleus (having order of size 10^{-15} metre).
4. Electron revolves around nucleus only in limited circular path and he assumed that electron does not radiate energy during its revolution in permitted paths.
5. Only those orbits are allowed whose orbit angular momentum is integral multiple of h2πh2π.
6. mvr = nh/2π, where n = 1, 2, 3, 4...
7. When electron absorbs energy, it jumps to higher orbit and when it comes back, it radiates

energy. This postulate explain spectra.

Achievements of Bohr's Theory

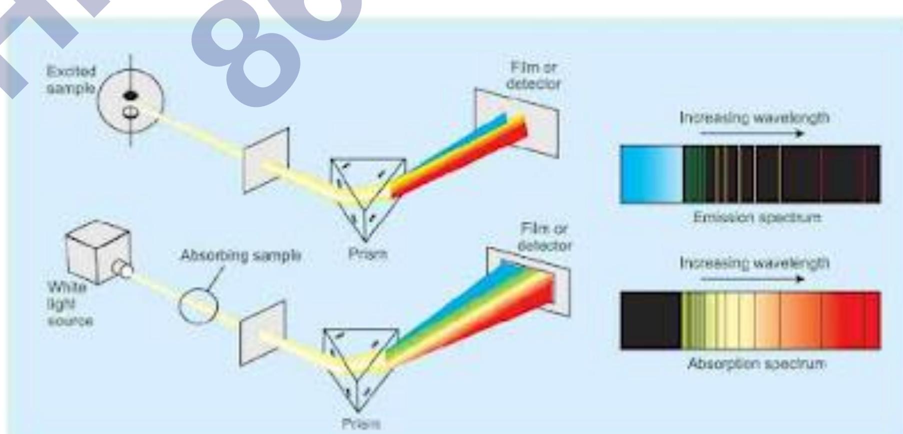
1. Bohr's theory has explained the stability of an atom.
2. Bohr's theory has helped in calculating the energy of electron in hydrogen atom and one electron species.
3. Bohr's theory has explained the atomic spectrum of hydrogen atom.

Limitations of Bohr's Model

1. The theory could not explain the atomic spectra of the atoms containing more than one electron or multielectron atoms.
2. Bohr's theory failed to explain the fine structure of the spectral lines.
3. Bohr's theory could not offer any satisfactory explanation of Zeeman effect and Stark effect.
4. Bohr's theory failed to explain the ability of atoms to form molecule formed by chemical bonds.
5. It was not in accordance with the Heisenberg's uncertainty principle.

Spectra

The most compelling evidence for the quantization of energy comes from spectroscopy. Spectrum word is taken from Latin word which means appearance. The record of the intensity transmitted or scattered by a molecule as a function of frequency or wavelength is called its spectrum.



Cosmic rays < gamma rays < x rays < ultraviolet rays < visible rays < infra red < micro waves < radio waves.

Line Spectrum of Hydrogen Atom

When electric discharge is passed through hydrogen gas enclosed in discharge tube under low pressure and the emitted light is analysed by a spectroscope, the spectrum consists of a large number of lines which are grouped into different series. The complete spectrum is known as hydrogen spectrum.

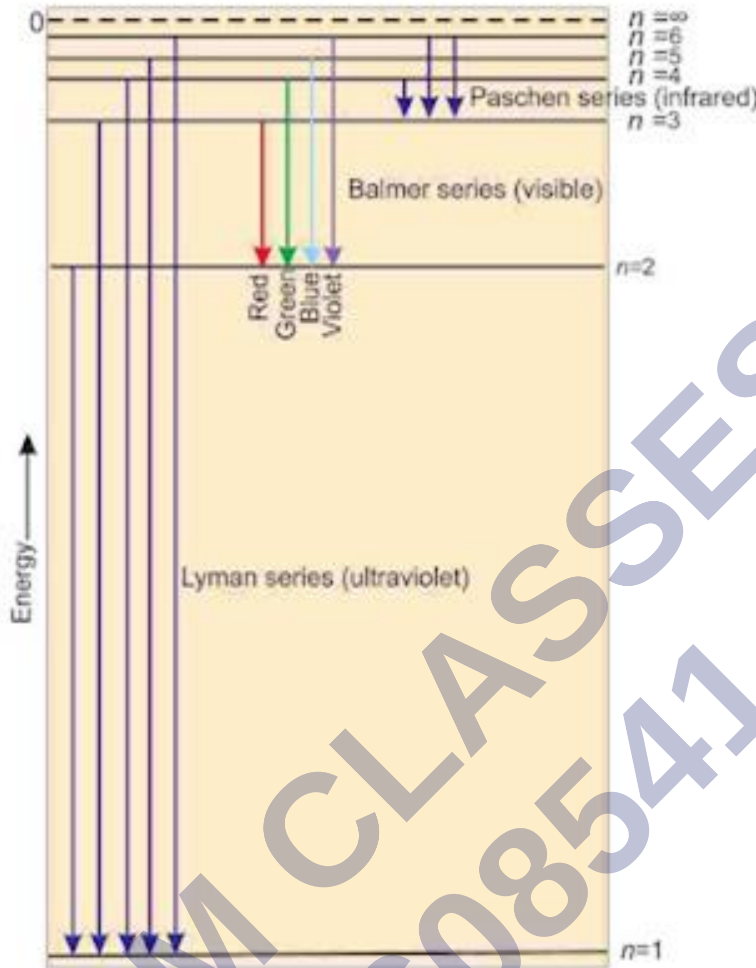
On the basis of experimental observations, Johannes Rydberg noted that all series of lines in the hydrogen spectrum could be described by the following expression:

wave number = 1λ = R(1n21 − 1n22)1λ = R(1n12 - 1n22)

R = Rydberg constant

R = 109678 cm^{-1}

Series	n_1	n_2	Spectral Region
Lyman	1	2,3....	Ultraviolet
Balmer	2	3,4....	Visible
Paschen	3	4,5....	Infrared
Brackett	4	5,6....	Infrared
Pfund	5	6,7....	Infrared



Zeeman Effect

When spectral line (source) is placed in magnetic field, spectral lines split up into sublines. This is known as zeeman effect.

Stark Effect

If splitting of spectral lines take place in electric field, then it is known as stark effect.

Dual Behaviour of Matter (de Broglie Equation)

De Broglie in 1924, proposed that matter, like radiation, should also exhibit dual behaviour i.e., both particle like and wave like properties. This means that like photons, electrons also have momentum as well as wavelength.

Assume light have wave nature, then its energy should be given by Planck's theory

$$E = h\nu E = h\nu \quad ...(i)$$

If it have particle nature, then its energy should be given by Einstein relation,

$$E = mc^2 \text{ ...(ii)}$$

On comparing equation (i) and (ii),

$$h\nu = mc^2$$

$$\lambda = hmc \text{ (for light) ...(iii)}$$

For other matter,

$$\lambda = hmv \text{ ...(iv)}$$

$$\lambda = hp \text{ ...(v)}$$

where p = momentum

This equation is called de Broglie equation.

Heisenberg's Uncertainty Principle

It states that, "It is impossible to measure simultaneously the exact position and exact momentum of a microscopic particle".

If uncertainty in position = Δ × and

Uncertainty in momentum = ΔP

When both are measured simultaneously, According to this principle,

$$\Delta \times . \Delta P \geq h4\pi$$

Quantum Numbers

There are a set of four quantum numbers which specify the energy, size, shape and orientation of an orbital. To specify an orbital only three quantum numbers are required while to specify an electron all four quantum numbers are required.

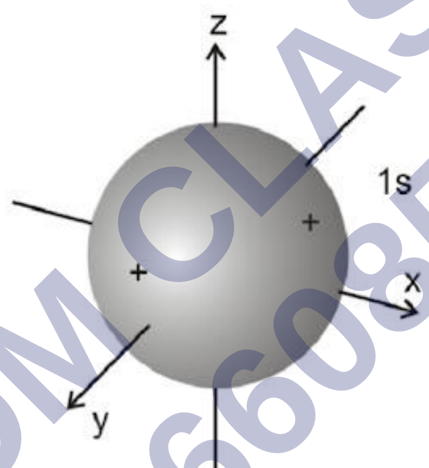
1. **Principal quantum number (n)**: It identifies shell, determines sizes and energy of orbitals. It is indicated by 'n' and its values are 1, 2, 3, 4...
2. **Azimuthal quantum number (l)**: Azimuthal quantum number. 'l' is also known as orbital angular momentum or subsidiary quantum number. l. It identifies sub-shell, determines the shape of orbitals, energy of orbitals in multi-electron atoms along with principal quantum number and orbital angular momentum, i.e., The number of orbitals in a sub shell = 2l + 1. For a given value of n, it can have n values ranging from 0 to n-1.
3. **Magnetic quantum number (ml)**: It gives information about the spatial orientation of the

orbital with respect to standard set of co-ordinate axis.For any sub-shell (defined by 'l' value) 2l+1 values of ml are possible. For each value of l, ml = – l, – (l–1), – (l–2)... 0,1...(l–2), (l–1), l

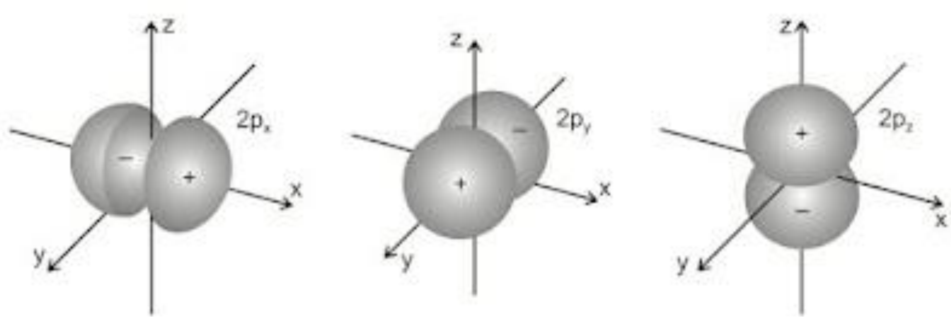
4. **Electron spin quantum number (ms)**: It refers to orientation of the spin of the electron. It can have two values +1/2 and -1/2. +1/2 identifies the clockwise spin and -1/2 identifies the anti-clockwise spin.

Shape of Atomic Orbitals

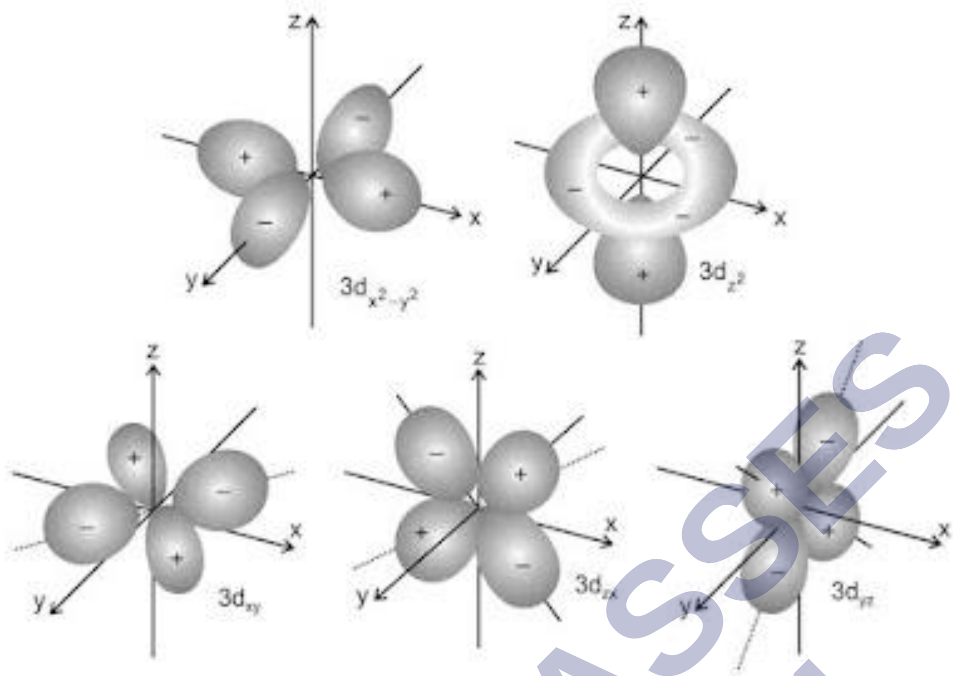
Shapes of s-orbitals: s-orbital is present in the s-sub shell. For this sub shell, l = 0 and ml = 0. Thus, s-orbital with only one orientation has a spherical shape with uniform electron density along all the three axes. The probability of Is electron is found to be maximum near the nucleus and decreases with the increase in the distance from the nucleus.



Shapes of p-orbitals: p-orbitals are present in the p-subshell for which l = 1 and ml can have three possible orientations –1, 0, +1. Thus, there are three orbitals in the p-subshell which are designated as px, py and pz orbitals depending upon the axis along which they are directed. The general shape of a p-orbital is dumb-bell consisting of two portions known as lobes.



Shapes of d-orbitals: d-orbitals are present in d-subshell for which l = 2 and ml = -2, -1, 0, +1 and +2. This means that there are five orientations leading to five different orbitals. d orbitals are of five types: d_{xy}, d_{yz}, d_{zx}, $d_{x^2-y^2}$, d_{z^2}

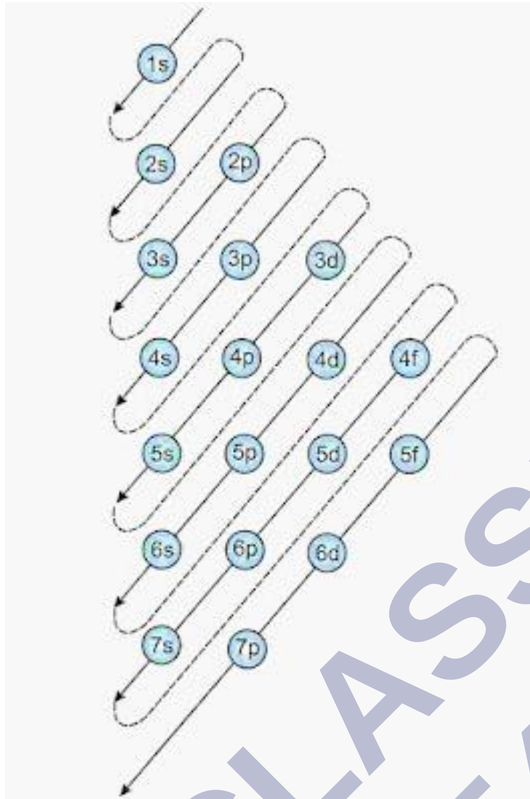


Electronic Configuration

Distribution of electron in various orbitals is known as electronic configuration. The electrons filled in orbitals must obey the following rules-

- Aufbau's principle
- Pauli's exclusion principle
- Hund's rule of maximum multiplicity

1. **Aufbau's principle:** According to this principle, orbitals with lowest energy are filled before the orbitals having higher energy.



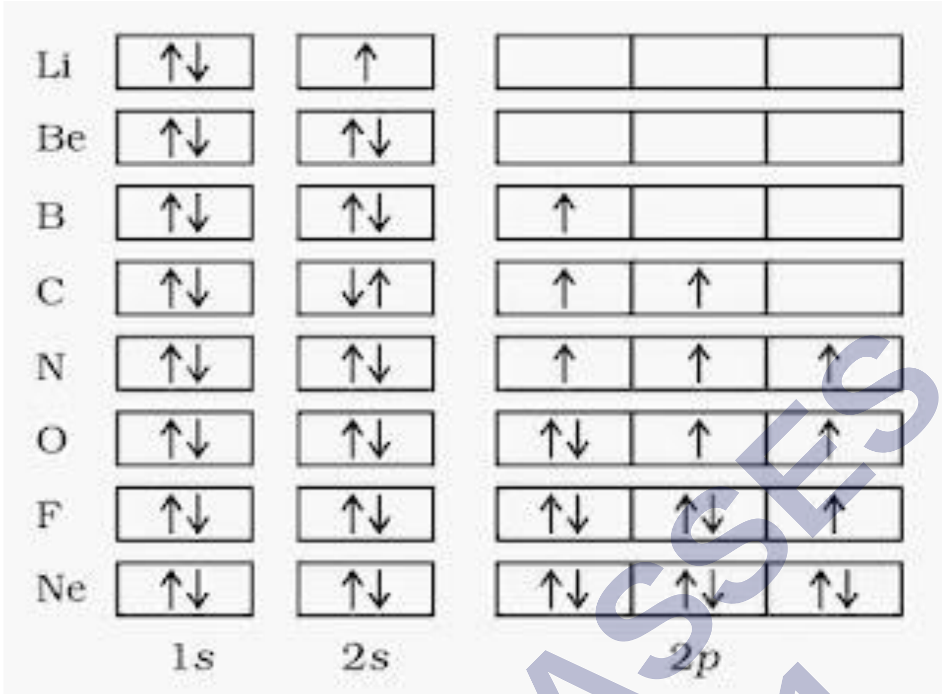
1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p

(n + l) rule (Bohr Bury's Rule)

According to this, The orbital which has lower value of (n + l) is lower in energy.

2. **Pauli's exclusion principle:** According to this principle, in an atom, no two electrons have same value of all the four quantum numbers. In the same orbital, electron always accommodate in opposite spins. An orbital can have a maximum of two electrons, with opposite spin.

3. **Hund's rule of maximum multiplicity:** According to this rule, electrons are distributed among the orbital of a subshell in such a way so as to give the maximum number of unpaired electrons with a parallel spin.



Discovery of Proton

Last Updated on July 6, 2022 By Mrs Shilpi Nagpal 3 Comments

Since the atom as a whole is electrically neutral and the presence of negatively charged particles in it was established ,therefore, it was thought that some positively charged particles must also be present in the atom.

Goldstein in 1886 performed discharge tube experiment in which he took perforated cathode and a gas at low pressure was kept inside the tube, as before.

1)On passing high voltage between the electrodes ,it was found that some rays were coming from the side of the anode which passed through the holes in the cathode and produced green fluorescence on the opposite glass wall coated with zinc sulphide. These rays were called anode rays or canal rays or positive rays.

Properties of anode rays

1)They travel in straight line.

2)They are made up of material particles.

3)They are positively charged.

4)The value of e/m depend upon the nature of gas taken inside the discharge tube.

5)The value of the charge on the particles constituent the anode rays is also found to depend upon the nature of the gas taken inside the discharge tube.

6)The mass of the particle constituting the anode rays is also found to be different for different gases taken in discharge tube.

The charge on these particles is found to be same as that on the electron i.e. 1.6 × 10-19 coulombs per gram.

The ratio, charge/mass, for each of the particle is found to be 9.58 × 10-24 g.

These particles were termed as protons.

A proton may be defined as that fundamental particle which carries 1 unit positive charge and has a mass nearly equal to that of hydrogen atom.

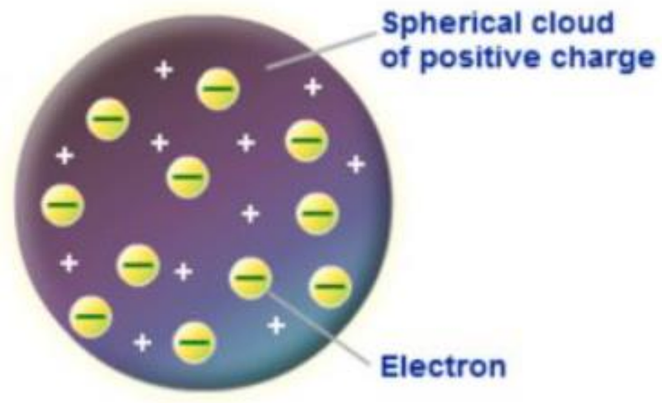
Discovery of neutron

Chadwick in 1932 ,performed some scattering experiment in which he bombarded some light elements like beryllium and boron with fast moving Alpha particles. He found that some new particles were emitted which carried no charge ie. were neutral but had a mass nearly equal to that of proton. This particle was termed neutrons.

A neutron may be defined as that fundamental particles which carries no charge but has a mass nearly equal to that of hydrogen atom or proton.

Rutherford’s Model of an Atom

Thomson’s model of atom



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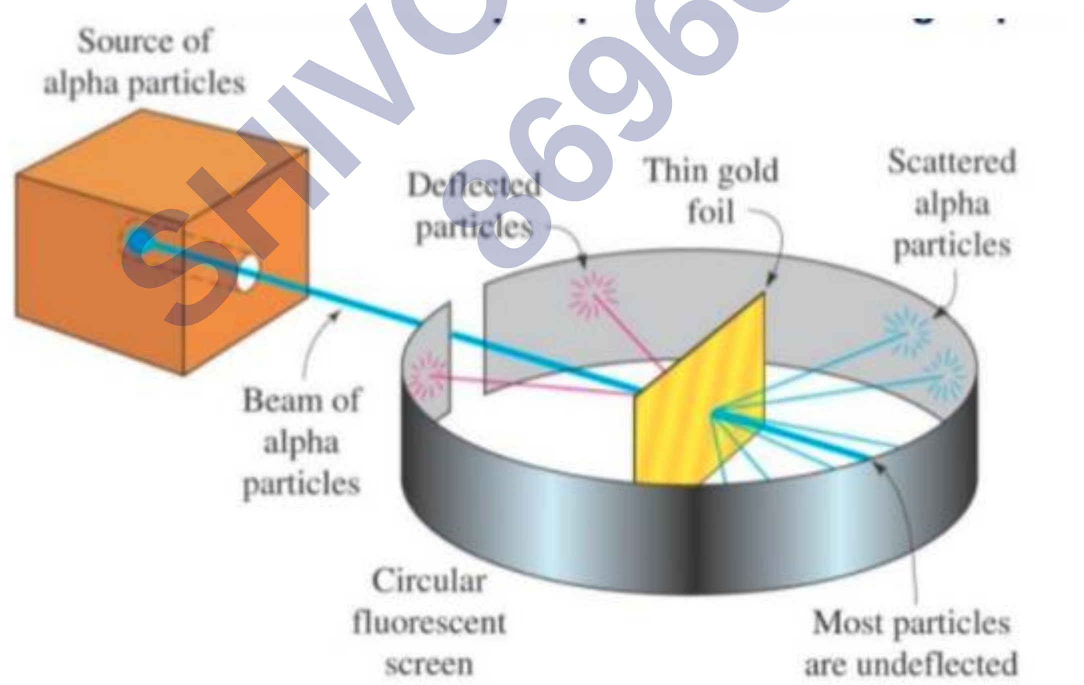
result of the balance between the repulsive forces between the electrons and their attraction towards the centre of the positive Sphere.This model is compared with a watermelon in which seeds are embedded or with a cake or pudding in which raisins are embedded. That is why this model is called as raisin pudding model a watermelon model.

Limitation

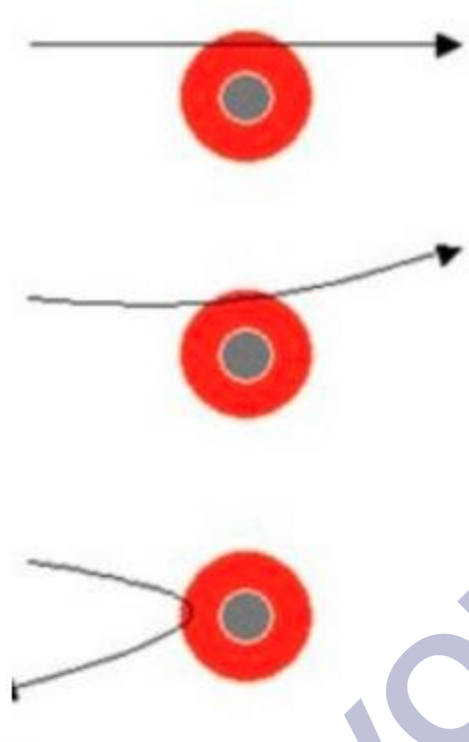
This model could not explain the stability of the atom.

Rutherford Model of atom



Rutherford in 1911, performed scattering experiment in which he bombarded thin walls of metals like gold, silver, Platinum or copper with a beam of fast moving Alpha particles. The source of Alpha particles was radium, a radioactive substance, placed in a block of lead. Slits were used to get a fine beam. The presence of Alpha particles at any point around the thin foil of gold after striking it was detected with the help of a circular zinc sulphide. The point at which an Alpha particle strikes this screen ,a flash of light is given out.

Observation



1) Most of the Alpha particles passed through the foil without undergoing any deflection.

2) Few Alpha particles underwent deflection through small angles.

3) Very few were deflected back through an angle greater than 90°

Conclusion

1)Since most of the Alpha particles passed through the foil without undergoing any deflection, there must be sufficient empty space within the atom.

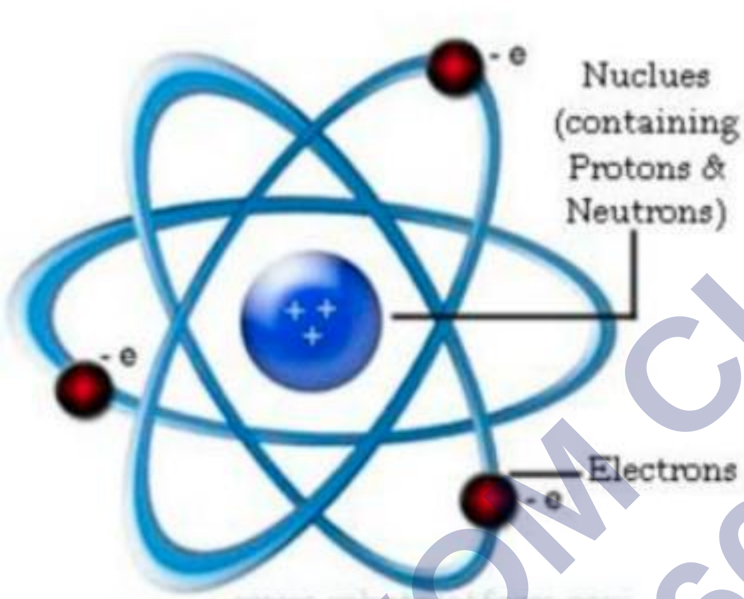
2)Since few alpha particles were deflected through small angles and alpha particles were positively charged particles, these could be deflected only by some positive body present within the atom. The alpha particles deflected were those which passed very close to this positive body.

3)Since some alpha particles were deflected back and alpha particles are heavy particle, these could be deflected back only when they strike some heavier body inside the atom.

4)Since the number of alpha particles deflected back is very very small, this shows that the heavy body present in an atom must be occupying a very very small volume.

The small heavy positively charged body present within the atom was called nucleus.

Rutherford Model of an atom



(1) Nucleus is very small in size, carries positive charge and in which the entire mass of the atom is concentrated.

(2) Since electrons have negligible mass ,the mass of the atom is mainly due to protons and neutrons.

(3) Protons and neutrons must be present in the nucleus.

(4) Extranuclear part is the space around the nucleus in which the electrons were distributed.

Drawback of Rutherford's Model of an atom

(1) Inability to explain the stability of atom

An atom consists of a small, heavy positively charged nucleus in the centre and the electrons were revolving around it. This model was compared with the solar system in which the planets were revolving around the sun and continue to move in their fixed circular paths because the force of attraction was balanced by the centrifugal force.

According to Maxwell's electromagnetic theory, whenever a charged particle like electron is revolving in a field of force like that of the nucleus, it loses energy continuously in the form of electromagnetic radiation. This is because when a particle is revolving, it undergoes acceleration due to change in direction even if the speed remains constant. Thus, the orbit of the revolving electron will keep on becoming smaller and smaller, following a spiral path and ultimately the electron should fall into the nucleus. The atom should collapse.

Rutherford model could not explain the stability of the atom.

(2) Inability to explain the line spectra of the elements.

(3) Inability to describe distribution of electrons and energies of electrons.

Electromagnetic Wave Theory

Electromagnetic wave theory

This theory was put forward by James clark Maxwell in 1864.

The main points of this theory are:

1)The energy is emitted from any source continuously in the form of radiations and is called the radiant energy.

2)The radiations consist of electric and magnetic fields oscillating perpendicular to each other and both perpendicular to the direction of propagation of the radiation.

3)The radiations possesses wave character and travel with the velocity of light.

The radiations are called electromagnetic radiations or electromagnetic waves.

4)These waves do not require any material medium for propagation.

Characteristics of a wave

1)Wavelength

Wavelength of a wave is defined as the distance between any two consecutive crest or trough.

It is represented by λ (Lambda) and is expressed in A° or m or cm or nm or pm.

1 A° = 10^{-8} cm = 10^{-10} m

1nm = 10^{-9} m, 1pm= 10^{-12} m

2)Frequency

Frequency of a wave is defined as the number of waves passing through a point in 1 seconds.

It is represented by ν (nu) and is expressed in hertz(Hz) or cycles/second or sec-1

3)Velocity

Velocity of a wave is defined as the linear distance travelled by the wave in 1 seconds.

It is represented by c and is expressed in cm/sec or m/sec.

4)Amplitude

Amplitude of a wave is the height of the crest or the depth of the trough.

It is represented by a and is expressed in the units of length.

5)Wavenumber

Wavenumber is defined as the number of waves present in 1 cm length.

It will be equal to the reciprocal of the wavelength.

It is represented by $\bar{v}$

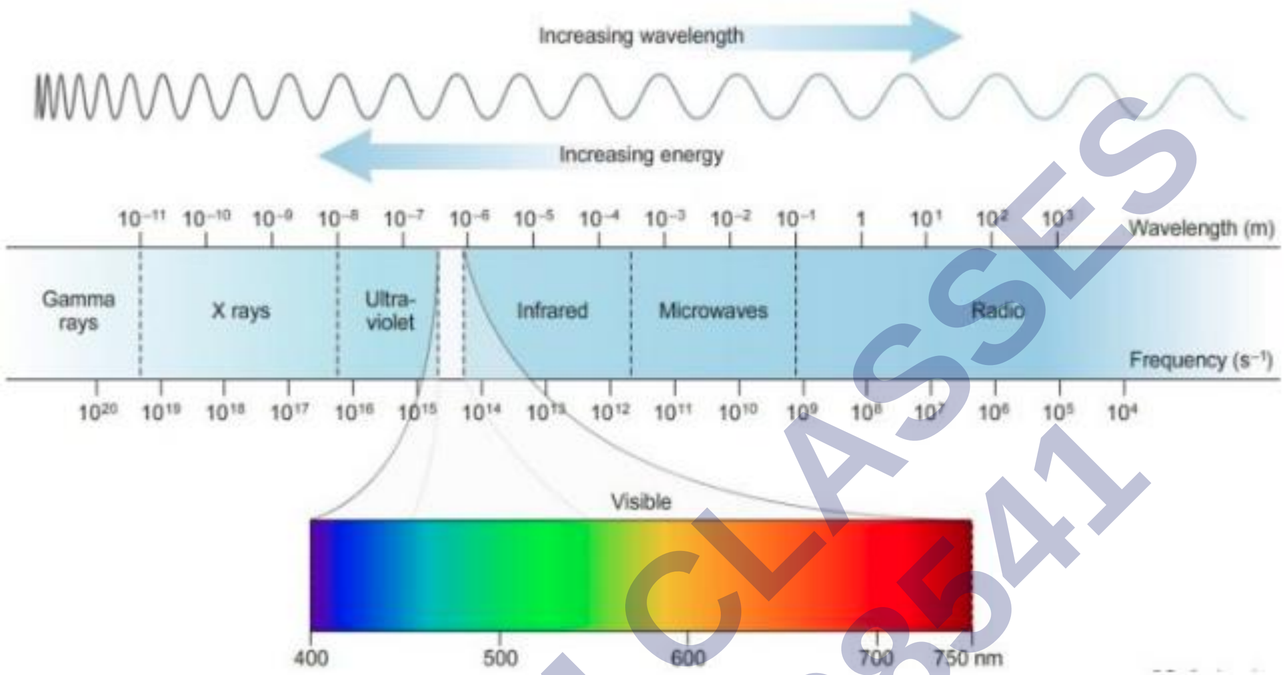
Relation between velocity ,wavelength and frequency of a wave

$C = \lambda v$

Electromagnetic Spectrum

The different types of electromagnetic radiations differ only in their wavelength and hence frequency.

Their Wave length increases in the following order:



Electromagnetic spectrum

When these electromagnetic radiations are arranged in order of their increasing wavelength or decreasing frequencies, the complete spectrum obtained is called electromagnetic spectrum.

Limitations of electromagnetic wave theory

It could not explain the :

1)The phenomena of black body radiation

2)The photoelectric effect

3)The variation of heat capacity of solid as a function of temperature.

4)The line spectra of atoms with special reference to hydrogen.

Black body radiation

If any substance with high melting point is heated, it first becomes red, then yellow and finally begins to glow with white and then blue light.

If the substance being heated is a black body (which is a perfect absorber and perfect radiator of energy ie. which can emit and absorb all frequencies) the radiations emitted is called black body radiation

The energy of any electromagnetic radiation is proportional to its intensity, ie. square of amplitude and is independent of its frequency or wavelength.

The change of colours shows that on heating ,the frequency of the radiations emitted is increasing.

Intensity versus wavelength

At a given temperature, intensity of radiation emitted increases with decrease of wavelength, reaches a maximum value at a particular wavelength and then start decreasing with further decrease of wavelength.

Photoelectric effect

When radiations with certain minimum frequency (ν_o) strike the surface of a metal, the electrons are ejected from the surface of the metal. This phenomenon is called Photoelectric effect

The electrons emitted are called photoelectrons.

1) The electrons are ejected only if the radiation striking the surface of the metal has at least a minimum frequency(ν_o) . If the frequency is less than ν_o , no electrons are ejected($h\nu_o$). This value is called threshold frequency.

The minimum energy required to eject the electrons is called work function(W_o)

2) The velocity of the electron ejected depends upon the frequency of the incident radiation and is independent of its intensity.

3) The number of photoelectrons ejected is proportional to the intensity of incident radiation.

Planck's Quantum Theory

Max Planck in 1900, put forward a theory known after his name as Planck's Quantum theory

The main points of this theory are :

1)The radiant energy is emitted or absorbed not continuously but discontinuously in the form of small discrete packets of energy. Each such packet of energy is called quantum. In case of light ,the quantum of energy is called Photon.

2)The energy of each quantum is directly proportional to the frequency of the radiation ie.

$E=h\nu$

Where h is the proportionality constant, called Planck's Constant.

Its value is 6.626×10^{-27} erg sec or 6.626×10^{-34} joule sec.

3)The total amount of energy emitted or absorbed by a body will be some whole number quanta.

Hence $E= nh\nu$

Explanation of black body radiation

When some solid substance is heated, the atoms of the substance are set into oscillations and emit radiations of frequency, ν. Now ,as heating is continued, more and more energy is being absorbed by the atoms and they emit radiations of higher and higher frequency. As red light has minimum frequency and yellow light has higher frequency, therefore the body on heating becomes first red, then yellow and so on.

Explanation of Photoelectric Effect

1)When light of some particular frequency falls on the surface of metal, the photon gives its entire energy to the electron of the metal atom. The electron will be detached from the metal atom only if the energy of the photon is sufficient to overcome the force of attraction of the electron by the nucleus. That is why photoelectrons are ejected only when the incident light has a certain minimum frequency (threshold frequency ν_0)

2If the frequency of the incident light is more than the threshold frequency ,the excess energy is imparted to the electron as kinetic energy.

Greater is the frequency of the incident light, greater is the kinetic energy of emitted electron.

3)When the intensity of light is increased, more electrons are ejected but the energies of these electrons are not altered.

Absorption and Emission Spectra

Electromagnetic spectrum

The electromagnetic spectrum consists of radiation of different wavelength and frequency.

An instrument used to separate the radiations of different wavelength is called spectroscope or spectrograph.

A spectroscope consists of a prism or a diffraction grating for the dispersion of radiation and a photographic film to examine the emergent radiation with the human eye.

The branch of science dealing with the study of spectra is called spectroscopy.

The spectra are broadly classified into:

1) Emission spectra

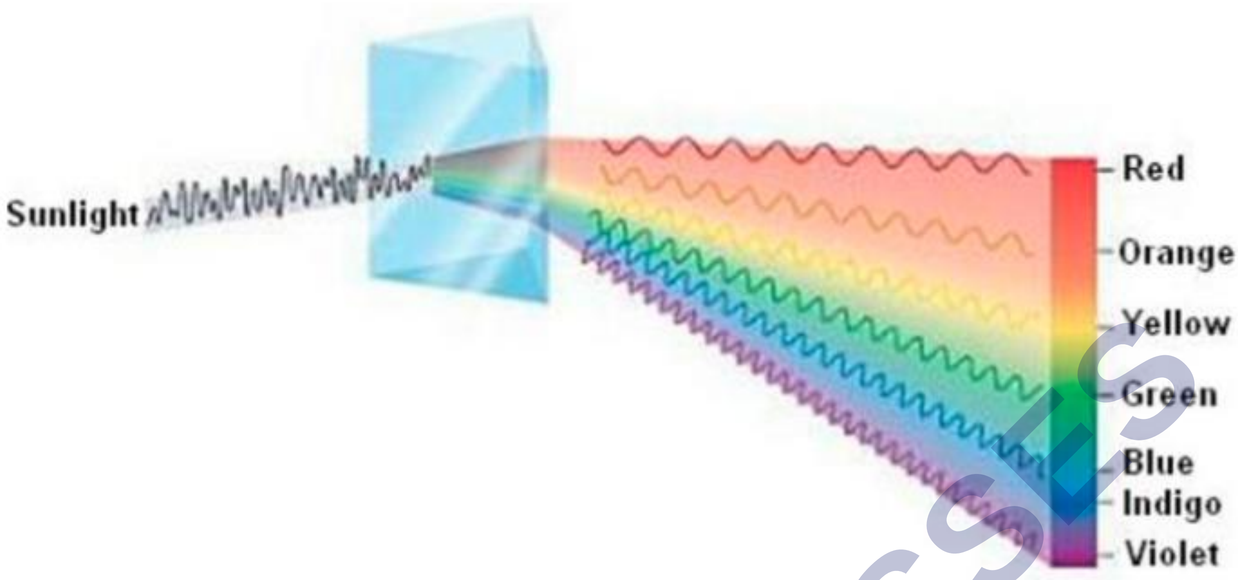
2) Absorption Spectra

Emission spectra

When the radiations emitted from some source eg: from the sun or by passing electric discharge through a gas at low pressure or by heating some substance to high temperature is passed directly through the prism and then received on the photographic plate, the spectrum obtained is called emission spectrum.

Depending upon the source of radiation, the emission spectra are mainly of two types:

1) Continuous spectrum



When white light from any source is analysed by passing through a prism, it is observed that it splits up into 7 different wide bands of colour. These colours are so continuous that each of them merges into the next. Hence the spectrum is called continuous spectrum.

On passing through the prism, red colour with the longest wavelength is deviated least while violet colour with shortest wavelength is deviated the most.

2) Line Spectra

When some volatile salt is placed in the bunsen flame or an electric discharge is passed through a gas at low pressure, light is emitted. The colour of light emitted depends upon the nature of substance.

Sodium emits yellow light while potassium gives out violet light.

If this light is resolved in a spectroscope, some isolated coloured lines are obtained on the photographic plates separated from each other by dark spaces. This spectrum is called line emission spectrum on line spectrum.

Each line in the spectrum corresponds to a particular wavelength. Sodium always gives two yellow lines.

Absorption spectra

White light from any source is passed through the solution or vapours of a chemical substance and then analysed by the spectroscope, it is observed that some dark lines are obtained. These dark lines are supposed to result from the fact that when the white light is passed through the chemical substance,, the radiations of certain wavelengths are absorbed, depending upon the nature of the element.

The dark lines are at the same place where coloured lines are obtained in the emission spectra for the same substance. The wavelength absorbed were same as were emitted in the emission spectra. The spectrum thus obtained is called absorption spectrum.

Emission spectrum of Hydrogen

When hydrogen gas at low pressure is taken in the discharge tube and the light emitted on passing electric discharge is examined with a spectroscope ,the spectrum obtained is called the emission spectrum of hydrogen.It is found to consist of a large number of lines which are grouped into different series ,named after the discoverer.

Rydberg in 1890 gave a very simple theoretical equation for the calculation of wavelength of these lines.

Where R is a constant ,called Rydberg constant and has a value of 109677 cm^{-1} or 1.097 × 107 m^{-1}

n1 and n2 are whole numbers and for a particular series, n1 is constant and n2 varies .

Rydberg's constant for hydrogen

Where Z is the atomic number.

Summary-

1. **Atomic number**: It is equal to the number of protons in the nucleus of an atom.
2. **Mass number**: It is equal to the sum of the positively charged protons (p) and electrically neutral neutrons (n).
3. **Isotopes**: Isotopes are the atoms of the same element which have the same atomic number but different mass numbers.
4. **Isobars:** Isobars are the atoms of different elements having the same mass number but different atomic numbers.
5. **Isoelectronic species**: These are those species which have same number of electrons.
6. **Radiations**: These are defined as the emission or transmission of energy through space in the form of waves.
7. **Electromagnetic waves**: The waves which consist of oscillating electric and magnetic fields are called electromagnetic waves.
8. **Electromagnetic radiations**: Those radiations which are associated with electric and magnetic field are called electromagnetic radiations.
9. **Electromagnetic spectrum**: The arrangement of the various types of electromagnetic radiations in the order of increasing or decreasing wavelengths or frequencies is known as electromagnetic spectrum.
10. **Wavelength (λ)**: It is the distance between successive points of equal phase of a wave.
11. **Frequency (f)**: The number of waves that pass a given point in one second is known as the frequency.
12. **Time period (T)**: Time taken by the wave for one complete cycle or vibration is called time period.
13. **Velocity (v)**: It is the distance travelled by a wave in one second.
14. **Wave number**: It is defined as the number of wavelengths per unit length.
15. **Threshold frequency**: It is the minimum frequency of light needed to cause the photoelectric effect.
16. **Continuous spectrum**: The combination of light of different frequencies in continuous manner is called continuous spectrum.
17. **Line spectrum**: The spectrum of atoms consist of sharp well-defined lines corresponding to definite frequencies is called line spectrum.

18. **Spectroscopy**: The study of emission or absorption spectra is called spectroscopy.

19. **Quantization**: The restriction of a property to discrete values and not continuous values is called quantization.

20. **Quantum mechanics**: The branch of science that takes into account the dual behaviour of matter is called quantum mechanics.

21. **Atomic orbital**: It is the region of space where the probability of finding the electron is maximum.

22. **Quantum numbers**: may be defined as a set of four numbers with the help of which we can get complete information about electron in an atom.

Fundamental Equation was deveoped by Schrodinger as $\hat{H}\psi = \hat{E}\psi$ where H= Hamiltonian

(i) Principal quantum number (n) :n = 1,2,3,4………….. Shell = K, L, M, N.......
(ii) Azimuthal Quantum number : For given value of n ,l = 0 to n-1
(iii) Magnetic Quantum number (m) : for subshell with 'l' value m_l=2l+1
(iv) Spin Quantum Number (m_s): $+^1/_2$ (↑), $-^1/_2$ (↓)

Schrodinger Equation

Quantum Numbers

- Aufbau Principle: In the ground state of atoms, the orbital's are filled according to increasing energies.
- P auli Exclusion Principle: No2 electrons in an atom can have sae set of four quantum numbers.
- Hund's rule: Pairing of electronsinthe orbitals belonging to same subshell does not take place until eachelectron belonging to the subshell is singly occupied.

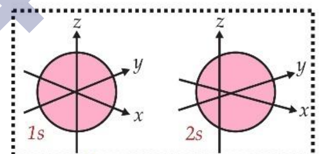
- Dual behaviour of atom i.e., particle and wavelike. De Broglie equation: $\lambda = \frac{h}{mv} = \frac{h}{p}$
- Heisenberg's Uncertainty Principle: It is impossible to determine simultaneously, the exact position and momentum of an electron

Quantum Technical Modal of Atom

Filing of orbitals in atom KE of rejected electron hv = hv0 + 1/2 m e v2

Structure of Atom

Shapes of orbitals



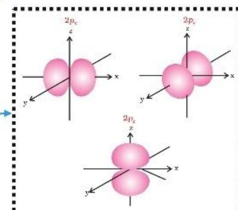
Electric Configuration of atoms

(i)$s^a p^b d^c$......... notation
(ii)Orbital diagram

s p d

Photoelectric Effect it was found By H.Hertz

s Orbitals:
Spherically symmetric
Size increases with increase in size in n, ie, 4s>3s>2s>1s

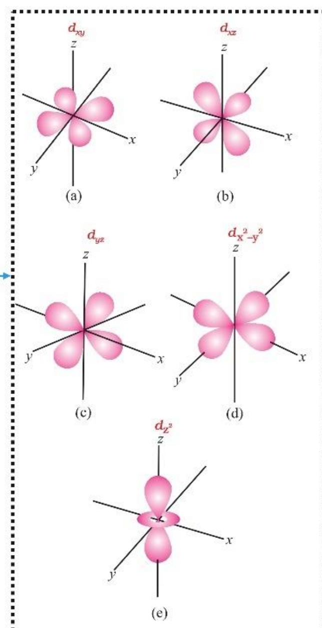


- It is the phenomenon of ejection of
- electrons from the surface of a
- metal when light of suitable
- frequency strikes on it.

Energy of orbit

p Orbitals:
Each p Orbitals consists of two sections called lobes on either side of plane passing through the nucleus.

d Orbitals
– "Clover leaf" distribution.
–Two angular nodes.



Developments leading to Bohar's Modal of Atom

Lower the value of (n+l) for an orbital, lower is its energy.

Dual nature ie wave like and particle like of the electromagnetic radiation.
• Experimental results regarding atomic spectra.
• Wave nature of electromagnetic radiation: It was given by James Maxwell.
Frequency (v) : Number of waves that pass a given point in one second. Unit – Hertz (Hz), Velocity of light = Frequency × Wave length
Wave number (v) : Number of wavelengths per unit length. Unit – m^{-1}
• Particle nature of electromagnetic radiation: Planck's quantum theory: E = h
Planck's constant (h) = 6.626 × 10^{-34} Js

Structure of Atom

Atomic Spectra

Types:

- Emission Spectra: Spectrum of radiation emitted by a substance that has absorbed energy.
- Absorption Spectra: It is like photographic negative of an emission spectra.
- Line / Atomic Spectra: Emission Spectra which do not show a continuous spread of wavelength from red to violet, rather they emit light only at specific wavelength with dark space between them.

$\bar{\nu} = 109677 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) cm^{-1}$ where

$n_1 = 1,2 \ldots\ldots\ldots\ldots n_2 = n_1+1, n_1+2 \ldots\ldots\ldots$

Series	n_1	n_2	Spectral Region
Lyman	1	2,3.........	Ultraviolet
Balmer	2	3,4.........	Visible
Paschen	3	4,5.........	Infrared
Brackett	4	5,6.........	Infrared
Pfund	5	6,7.........	Infrared

Isobars:

Atoms of different elements with different atomic number but same mass number. (Ca and Ar)

Discovery of Election

By J.J.Thomson Charge to mass ratio of electron $= 1.758820 \times 10^{11}$ C kg^{-1}

Charge an electron $= 1.6022 \times 10^{-19}$C

Mass of electron $= 9.1094 \times 10^{-31}$Kg

Discovery of Proton

By Ernest Rutherford

Charge on proton $= +1.6022 \times 10^{-19}$C

Mass of Proton$= 1.672 \times 10^{-27}$ Kg

Discovery of Neutron

By James Rutherford

Charge on neutron = 0

Mass of neutron$= 1.675 \times 10^{-27}$ Kg

Isotopes

Atoms of same element having same atomic number but different mass number. (Isotopes of hydrogen) Protium $^1H_1$, Deuterium $^2D_1$ and Tritium $^3T_1$.

Mass Number (A)

Number of protons (Z) + number of neutrons (n)

Atomic Number (Z)

Number of protons in nucleus of an atom or Number of electrons in a neutral atom

Thomson Model of Atom: (Watermelon Model)

Atom possesses a spherical shape in which the positive charge is uniformly distributed.

Rutherford's Nuclear Model of Atom

Postulates:

- **Positive charge and most of the mass of atoms was densely concentrated in extremely small region (ie) nucleus.**
- **Nucleus is surrounded by electrons that move around the nucleus with high speed in circular path called orbits.**
- **Electrons and nucleus are held together by electrostatic forces of attraction.**

Drawbacks:

- **It cannot explain the stability of an atom.**
- **It does not say anything about the electronic structure of atoms.**

Bohr's Model for Hydrogen Atom

Postulates:

- Electron in H atom can move around the nucleus in a circular path of fixed radius and energy called as orbits. These orbits are arranged concentrically around the nucleus.
- Each of these orbits has a definite energy known as energy levels or stationary states.
- When an electron jumps from a lower energy level to higher one, some energy is absorbed.
- $\nu = \frac{E}{h} = \frac{E_2 - E_1}{h}$ Bohr's frequency rule.

Angular momentum of electron: $m_e vr = n \frac{h}{2\pi}$ n=1,2,3.....

Limitations:

- Unable to account for finer details of H atom. Spectrum observed by sophisticated spectroscopic techniques.
- Could not explain the ability of atoms to form molecules by chemical bonds.

Important Questions

Multiple Choice questions-

Question 1. Which of the following pair of ions have same paramagnetic moment?

(a) Cu^{+2}, Ti^{+3}

(b) Mn^{+2}, Cu^{+2}

(c) Ti^{+4}, Cu^{+2}

(d) Ti^{+3}, Ni^{+2}

Question 2. The charge to mass ratio of α – particles is approximately …… the charge to mass ratio of protons

(a) Twice

(b) Half

(c) Four times

(d) Six times

Question 3. The frequency of a wave of light is $12 \times 10^{14} s^{-1}$. The wave number associated with this light

(a) 5×10^{-7}m

(b) $4 \times 10^{-8} cm^{-1}$

(c) $2 \times 10^{-7} m^{-1}$

(d) $4 \times 10^{4} cm^{-1}$

Question 4. In a multi – electron atom, which of the following orbitals described by the three quantum numbers will have the same energy in the absence of magnetic acid and electric fields? (a) n = 1, l = 0, m = 0 (b) n = 2, l = 0, m = 0 (c) n = 2, l = 1, m = 1 (d) n = 3, l = 2, m = 1 (e) n = 3, l = 2, m = 0

(a) (a) and (b)

(b) (b) and (c)

(c) (c) and (d)

(d) (d) and (e)

Question 5. The electronic transitions from n = 2 to n = 1 will produce shortest wavelength in (where n = principal quantum state)

(a) Li^{2+}

(b) He^{+}

(c) H

(d) H^+

Question 6. In a hydrogen atom, if energy of an electron in ground state is 13.6 eV, then that in the 2nd excited state is

(a) 1.51 eV

(b) 3.4 eV

(c) 6.04 eV

(d) 13.6 eV

Question 7. The credit of discovering neutron goes to

(a) Rutherford

(b) Thomson

(c) Goldstein

(d) Chadwick

Question 8. The maximum number of electrons that can be accommodated in fifth energy level is

(a) 10

(b) 25

(c) 50

(d) 32

Question 9. According to Aufbaus principle, which of the three 4d, 5p and 5s will be filled with electrons first

(a) 4d

(b) 5p

(c) 5s

(d) 4d and 5s will be filled simultaneously

Question 10. A hydrogen atom in its ground state absorbs 10.2 eV of energy. The orbital angular momentum is increased by (Given Planck constant h = 6.6×10^{-34} Jsec)

(a) 1.05×10^{-34} Jsec

(b) 3.16×10^{-34} Jsec

(c) 2.11×10^{-34} Jsec

(d) 4.22×10^{-34} Jsec

Question 11. The ionization enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from n = 1 to n = 2 is

(a) 8.51×10^5 Jmol-1

(b) 6.56×10^5 Jmol-1

(c) 7.56×10^5 Jmol-1

(d) 9.84×10^5 Jmol$^{-1/sup>}$

Question 12. For principal quantum number n = 4, the total number of orbitals having l = 3 is

(a) 3

(b) 7

(c) 5

(d) 9

Question 13. Maximum number of electrons in a subshell with l = 3 and n = 4 is

(a) 10

(b) 12

(c) 14

(d) 16

Question 14. Which hydrogen-like species will have same radius as that of Bohr orbit of hydrogen atom?

(a) n = 2, Li^{2+}

(b) n = 2, Be^{3+}

(c) n = 2, He^{+}

(d) n = 3, Li^{2+}

Question 15. The magnetic quantum number specifies

(a) Size of orbitals

(b) Shape of orbitals

(c) Orientation of orbitals

(d) Nuclear Stability

Very Short:

1. How many total electrons are present in nitrate ion?
2. The nucleus of the atom of an element does not contain a neutron. Name the element and what does its nucleus consists of.
3. What are nucleons?

4. Write electronic configurations of Chromium (At. Np. = 24).

5. Which of the following has the smallest de-Broglie wavelength? O_2, H_2, a proton, an electron

6. How many unpaired electrons are there is a carbon atom in the ground state?

7. What type of spectrum is obtained when light emitted from the discharge tube containing hydrogen gas is analyzed?

8. What is the maximum number of electrons in an atom having n = 3, l = 1 and s = + $\frac{1}{2}$?

9. Name the spectral line in the spectrum of H-atom obtained when an electron jumps from n = 4 to n = 2.

10. Give some examples of electromagnetic radiation.

Short Questions:

1. Enumerate the important characteristics of anode-rays (or positive rays). How this study led to the discovery of proton?
2. What are anode-rays? Illustrate their formation by a diagram.
3. Describe the important properties of cathode-rays. What is concluded about the nature of these rays?
4. What are the main features of Rutherford's model of an atom?
5. What is meant by the dual nature of radiation?
6. Describe the drawback to Rutherford's model of the atom.
7. What is the value of?
   (i) Charge to mass ratio (e/m) of electrons,
   (ii) Charge of electrons,
   (iii) Mass of an electron?

Long Questions:

1. Describe the shape of s – and p – orbitals What do you mean by node or nodal surface?
2. How does the Schrodinger wave equation help to understand the probability of finding the electron near the nucleus? What do you mean by an orbital?
3. How many nucleons are present in an atom Nobelium, No? How many electrons are present in the atom? How many nucleons may be considered neutrons?
4. Complete the following table:

Particle	Atomic No.	Mass No.	No. of electrons	No. of protons	No. of neutrons
Sodium atom	11	—	—	—	12
Aluminium ion	—	27	10	—	—
Chloride ion	—	—	18	—	18
Phosphorus atom	—	31	—	15	—
Cuprous ion	—	—	28	—	35

5. Find the number of protons, electrons an-d neutrons in (a) $13^{27}A^{3+}$

Assertion Reason Questions:

1. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   Assertion (A) : All isotopes of a given element show the same type of chemical behaviour.

   Reason (R) : The chemical properties of an atom are controlled by the number of electrons in the atom.

   (i) Both A and R are true and R is the correct explanation of A.

   (ii) Both A and R are true but R is not the correct explanation of A.

   (iii) A is true but R is false.

   (iv) Both A and R are false.

2. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   Assertion (A) : Black body is an ideal body that emits and absorbs radiations of all frequencies.

   Reason (R) : The frequency of radiation emitted by a body goes from a lower frequency to higher frequency with an increase in temperature.

   (i) Both A and R are true and R is the correct explanation of A.

   (ii) Both A and R are true but R is not the explanation of A.

   (iii) A is true and R is false.

   (iv) Both A and R are false.

Case Study Based Question:

1. The atomic theory of matter was first proposed on affirm scientific basis by John Dalton, a British schoolteacher in 1808. His theory, called Dalton's atomic theory, regarded the atom as the ultimate particle of matter Dalton's atomic theory was able to explain the law of conservation of mass, law of constant composition and law of multiple proportion very successfully. However, it failed to explain the results of many experiments. In mid 1850s many scientists mainly Faraday began to study electrical discharge in partially evacuated tubes, known as cathode ray discharge tubes. Electrical discharge carried out in the modified cathode ray tube led to the discovery of canal rays carrying positively charged particles. The characteristics of these positively charged particles are listed below.

   1) Unlike cathode rays, mass of positively charged particles depends upon the nature of gas present in the cathode ray tube. These are simply the positively charged gaseous ions.

   2)The charge to mass ratio of the particles depends on the gas from which these originate.

   3) Some of the positively charged particles carry a multiple of the fundamental unit of electrical charge.

   4) The behaviour of these particles in the magnetic or electrical field is opposite to that observed for electron or cathode rays.

   The smallest and lightest positive ion was obtained from hydrogen and was called proton. This positively charged particle was characterised in 1919. Later, a need was felt for the presence of electrically neutral particle as one of the constituent of atom. These particles were discovered by Chadwick (1932)by bombarding a thin sheet of beryllium byα-particles. When electrically neutral particles having a mass slightly greater than that of protons were emitted. He named these particles as neutrons. J. J. Thomson, in 1898, proposed that an atom possesses a spherical shape (radius approximately 10–10 m) in which the positive charge is uniformly distributed. The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement Many different names are given to this model, for example, plum pudding, raisin pudding or watermelon. This model can be visualised as a pudding or watermelon of positive charge with plums or seeds (electrons)embedded into it. An important feature of this model is that the mass of the atom is assumed to be uniformly distributed over the atom. Rutherford and his students (Hans Geiger and Ernest Marsden) bombarded very thin gold foil with α–particles. Rutherford's famous α–particle scattering experiment. The observations of Scattering experiment are as follows-:

   (i) most of the α–particles passed through the gold foil undeflected.

   (ii) a small fraction of the α–particles was deflected by small angles.

   (iii) a very few α–particles (~1 in 20,000)bounced back, that is, were deflected by nearly 180°.

On the basis of observations and conclusions from this experiment, Rutherford proposed the nuclear model of atom. According to this model:

(i) The positive charge and most of the mass of the atom was densely concentrated in extremely small region. This very small portion of the atom was called nucleus by Rutherford.

(ii) The nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called orbits. Thus, Rutherford's model of atom resembles the solar system in which the nucleus plays the role of sun and the electrons that of revolving planets.

(iii) Electrons and the nucleus are held together by electrostatic forces of attraction.

1) The atomic theory of matter was first proposed on affirm scientific basis by.

(a) John Dalton

(b) Ernest Rutherford

(c) J. Thomson

(d) Henry Moseley

2) The cathode rays start from ………. and move towards the …………

(a) Anode , Cathode

(b) Centre , Anode

(c) Cathode , Anode

(d) Cathode , Centre

3) Negatively charged particles in atoms , called ……….

(a) Protons

(b) electrons

(c) Neutron

(d) Positron

(4) The smallest and lightest positive ion was obtained from ………. and was called proton.

(a) Oxygen

(b) Nitrogen

(c) Carbon

(d) Hydrogen

(5) Electrically neutral particles having a mass slightly greater than that of protons, these particles termed as …………

(a) Protons

(b) electrons

(c) Neutron

(d) Positron

2. The presence of positive charge on the nucleus is due to the protons in the nucleus. As established earlier, the charge on the proton is equal but opposite to that of electron. Atomic number (Z) = number of protons in the nucleus of an atom = number of electrons in a neutral atom. protons and neutrons present in the nucleus are collectively known as nucleons. The total number of nucleons is termed as mass number (A) of the atom.

mass number (A) = number of protons (Z) + number of neutrons (n).

Isobars are the atoms with same mass number but different atomic number for example, $6^{14}C$ and $7^{14}N$. On the other hand, atoms with identical atomic number but different atomic mass number are known as Isotopes. For example, considering of hydrogen atom again, 99.985%of hydrogen atoms contain only one proton. This isotope is called protium ($1^{1}H$). Rest of the percentage of hydrogen atom contains two other isotopes, the one containing 1 proton and 1neutron is called deuterium ($^{2}{}_{1}D$, 0.015%)and the other one possessing 1 proton and 2neutrons is called tritium ($^{1}{}_{3}T$)..the studies of interactions of radiations with matter have provided immense information regarding the structure of atoms and molecules. Niels Bohrutilised these results to improve upon the model proposed by Rutherford. Two developments played a major role in the formulation of Bohr's model of atom. These were:

(i) Dual character of the electromagnetic radiation which means that radiations possess both wave like and particle like properties, and

(ii) Experimental results regarding atomic spectra.

James Maxwell (1870) was the first to give a comprehensive explanation about the interaction between the charged bodies and the behavior of electrical and magnetic fields on macroscopic level. He suggested that when electrically charged particle moves undercalculation, alternating electrical and magnetic fields are produced and transmitted. These fields are transmitted in the forms of waves called electromagnetic waves or electromagnetic radiation. radiations are characterised by the properties, namely, frequency (ν) and wavelength (λ).The SI unit for frequency (ν) is hertz(H_z, s^{-1}), after Heinrich Hertz. It is defined as the number of waves that pass a given pointing one second. Wavelength should have the units of length and as you know that the SI units of length is meter (m). Since electromagnetic radiation consists of different kinds of waves of much smaller wavelengths, smaller units are used. In vacuum all types of electromagnetic radiations, regardless of wavelength, travel at the same speed, i.e., $3.0 \times 10^8 m s^{-1}$ ($2.997925 \times 10^8 ms^{-1}$, to be precise). This is called speed of light and is given the symbol 'c'. The frequency (ν), wavelength (λ) and velocity of light(c) are related by the following equation .

$c = \nu \lambda$

The other commonly used quantity specially in spectroscopy, is the wavenumber. It is defined as the number of wavelengths per unit length. Its units are reciprocal of wavelength unit, i.e., m^{-1}. However commonly used unit is cm^{-1}

1) The presence of positive charge on the nucleus is due to the ………… in the nucleus.

(a) Protons

(b) Neutrons

(c) Electron

(d) Nucleons

2) Atomic Number is denoted by ………..

(a) A

(b) Z

(c) N

(d) M

3) Atomic Mass number is denoted by ………….

(a) M

(b) Z

(c) N

(d) A

4) ……….. are the atoms with same mass number but different atomic number.

(a) Isotopes

(b) Allotropes

(c) Isobars

(d) None of above

5) Atoms with identical atomic number but different atomic mass number are known as ..

(a) Isotopes

(b) Allotropes

(c) Isobars

(d) None of above

Answer Key:

MCQ

1. (a) Cu^{+2}, Ti^{+3}
2. (b) Half
3. $4 \times 10^4 cm^{-1}$
4. (d) (d) and (e)
5. (a) Li^{2+}
6. (a) 1.51 eV
7. (d) Chadwick
8. (c) 50
9. (9) 5s
10. (a) 1.05×10^{-34} Jsec
11. (d) $9.84 \times 10^5 J\ mol^{-1}$
12. (b) 7
13. (c) 14
14. (b) n = 2, Be^{3+}
15. (c) Orientation of orbitals

Very Short Answer:

1. No. of electrons in NO3– ion
= No. of electrons on N + No. of electrons on 3 oxygen atoms + one ē
= 7 + 3 × 8 + 1 = 32 electrons.

2. The nucleus of hydrogen. It contains only one proton.

3. The neutrons and protons present in the nucleus of an atom are collectively called nucleons.

4. Cr = 24 = $1s^2$, $2s^2$ $2p^6$, $3s^2$ $3p^6$ $3d^5$, $4s^1$.

5. According to the de-Broglie equation $\lambda = \frac{h}{m \times v}$ for same value of velocity $\lambda \propto \frac{1}{m}$

∴ O_2 molecule has shortest wavelength.

6. C = 6 = $1s^2$, $2s^2$, $2p^1x$ $2p^1y$. There are only two unpaired electrons.

7. Emission line spectrum.

8. Three electrons (one each in $3p_x$' $3p_y$', $3p_z$').

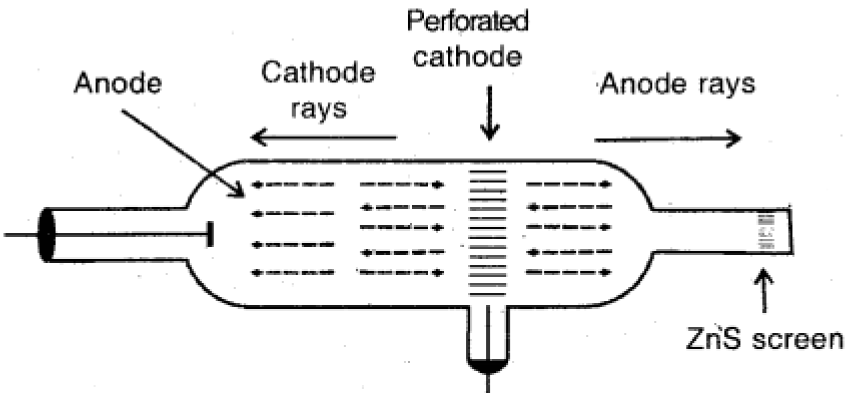
9. Balmer Series.

10. Y-rays, X-rays, UV-rays, visible rays, radio waves, etc.

Short Answer:

Ans: 1. The mass of positive particles which constitute these rays depend upon the nature of the gas in the tube. The charge/mass (e/m) ratio of anode-rays is not constant but depends upon the nature of gas in the tube. The value of e/m is greatest for the lightest gas, hydrogen the electric charge on a lightest positively charged particle from hydrogen gas was found to be exactly equal in magnitude but opposite in sign to that of the electron. This lightest positively charged particle from hydrogen gas was named the proton. The mass of a proton is almost 1836 times that of the electron.

Ans: 2. Anode-rays. If a perforated cathode is used in the discharge tube experiment, it is found that a certain type of radiation also travels from anode to cathode. These are called anode rays or positive rays.



Production of anode rays

Ans: 3. The cathode rays possess the following properties:

1. Travel in straight lines perpendicular to the surface of the cathode.
2. Consists of material particles.
3. Have got the heating effect.
4. Consists of negatively charged particles.
5. Produce X-rays when they strike against hard metals like copper, tungsten, platinum, etc.
6. Produce fluorescence when they strike glass or certain other materials like zinc sulfide.
7. Penetrate through thin aluminum foils and other metals.
8. Affect the photographic plates.

Ans: 4. The main features of this model are:

1. Atom is spherical and consists of two parts: Nucleus and extra-nuclear part.

2. The entire mass and entire positive charge are concentrated in a very small region at the center known as the nucleus.

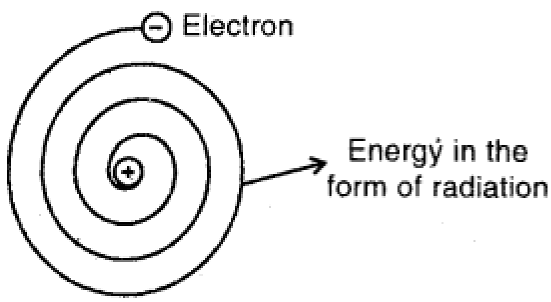
3. The space surrounding the nucleus known as the extra-nuclear part is negatively charged so an atom as a whole is neutral.

4. Most of the extra-nuclear part is empty.

5. The electrons are not stationary but are revolving around the nucleus at very high speeds like planets revolving around the Sun.

Ans: 5. The fact that light energy is carried in terms of packets of energy (i.e., photons) as suggested by Planck's theory means that light has a particle character. At the same time, the fact light has a wave character. These experimental facts led Einstein to suggest that light has a dual character, i.e., it behaves both like a wave and like a particle.

Ans: 6. The main drawback is that it could not explain the stability of an atom. Maxwell has shown that when electric charge is subjected to acceleration, it emits energy in the form of radiations. In Rutherford's model of the atom, electrons are orbiting the nucleus and hence the direction of their velocity is constantly changing, i.e., electrons are accelerating.
This will cause the electrons will have lesser and lesser energy and will get closer and closer to the nucleus until at last, it spirals into the nucleus and thus does not provide a stable model of the atom.



Ans: 7. J. Thomson determined the value of e/m for electron by the study of deflection of electron beam under the simultaneous influence of electric and magnetic field perpendicular to each other, the e/m value is 1.76 × 108 coulomb per gram of electrons

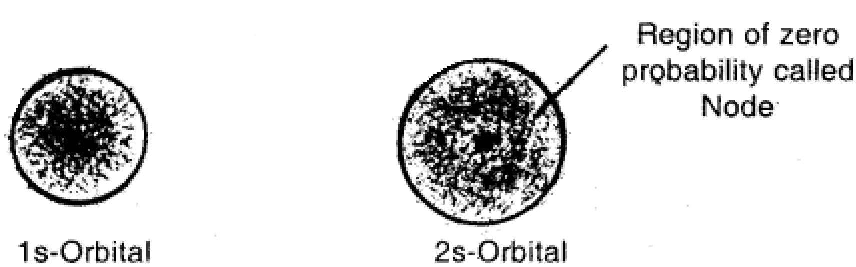
The charge of electrons was measured by Millikan in 1909 by his famous 'oil drop' experiment. It was found to be 1.60 × 10-19 coulombs.

The mass of electrons is 9.1 × 10-28 g.

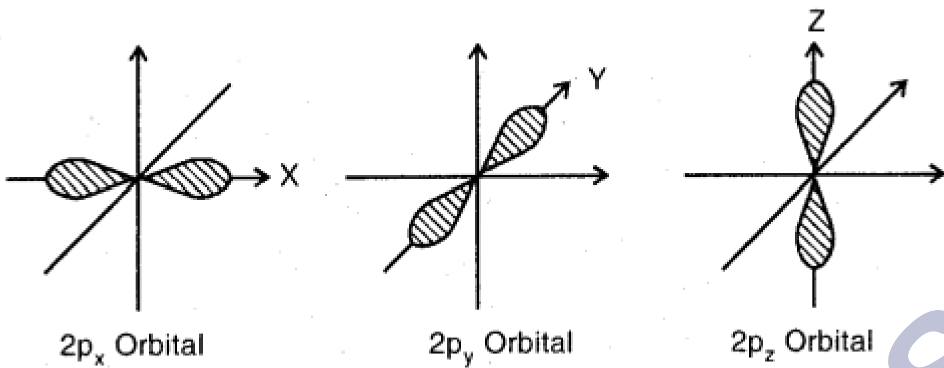
Long Answer:

Ans: 1. Shapes of Orbitals:

s-orbitals: These are spherically symmetrical and non-directional. Shapes of 1s and 2s orbitals are shown in Fig. The effective volume of 2s orbital is larger than is orbital. Another important feature of 2s orbital is that there is a spherical shell within 2s (region without dots) where the probability of finding the electron is zero. This is called a node or a nodal surface. There are (n - 1) nodes in an s-orbital (where n is the energy level).



p-orbitals: There are three p-orbitals designated as px', py' or pz' which are oriented along the three mutually perpendicular axis x, y, and 2. Each, orbital consists of two lobes symmetrical about the particular axis and has a dumbbell shape. The two lobes are separated by a nodal plane.



Shapes of three 2p orbitals

The two lobes of each orbital are separated by a plane having x zero electron density. This plane is known as a nodal plane.

Ans: 2. Probability Picture of Electrons:

Schrodinger incorporated the requirements of the uncertainty principle and de Broglie's concept of matter waves and proposed a mathematical equation to describe the behavior of an electron in an atom. The equation was known as the Schrodinger wave equation.

The Schrodinger wave equation is

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

where x, y, and z are three space coordinates,

m is the mass of the electron,

h is Planck's, constant

E is the total energy and V is the potential energy of the electron, ϕ (Greek letter psi) is the amplitude of the wave, called wave function, $\frac{\partial 2\psi}{\partial x2}$ refers to the second derivative of ϕ with respect to x only and so on.

The solution of this equation gave the mathematical expression which gives information about the various energy states and other measurable properties such as the radiation frequencies emitted or absorbed for the hydrogen atom. The solutions of the Schrodinger wave equation are called wave functions and are denoted by the symbol ϕ.

The physical significance of wave function: In the physical sense ϕ gives the amplitude of the wave associated with the electron. We know that in the case of light waves, the square of the amplitude, of the wave at a point is proportional to the intensity of light. Extending the same concept of electron wave motion, the square of the wave function, ϕ2 may be taken as the intensity of electrons at any point.

In other words, ϕ^2 determines the probability density. Thus, ϕ^2 has been called the probability density and ϕ the probability amplitude. Thus, the solutions of the Schrodinger wave equation replace the discrete energy levels or orbits proposed by Bohr and led to the concept of the most probable regions in space in terms of $\phi 2^2$.

A large value of ϕ^2 means a high probability of finding the electron at that place and a small value of ϕ^2 means low probability. If ϕ^2 is almost zero at a particular point, it means that the probability of finding the electron at that point is negligible. Therefore, the wave mechanics approach gives meaningful wave functions which describe the position and energy levels of electrons in an atom.

Concept of Orbital: An orbital is a region in space around the nucleus where the probability of finding the electrons is maximum.

Ans: 3. Nucleons = 254, electrons = 102 and neutrons 254 - 102 = 152.

Ans: 4.

Particle	Atomic No.	Mass No.	No. of electrons	No. of protons	No. of neutrons
Sodium atom	11	23	11	11	12
Aluminium ion	13	27	10	13	14
Chloride ion	17	35	18	17	18
Phosphorus atom	15	31	15	15	16
Cuprous ion	29	64	28	29	35

Ans: 5.

Name of the particle	Mass No.	Atomic No.	Protons	No. of Electrons	Neutrons
Oxygen	16	8	8	8	8
Sodium ion	23	11	11	10	12
Bromine	80	35	35	35	45

Assertion Reason Answer:

1. (i) Both A and R are true and R is the correct explanation of A.
2. (ii) Both A and R are true but R is not the explanation of A.

Case Study Answer:

1. Answer:

(1) (a) John Dalton

(2) (c) Cathode, Anode

(3) (b) electrons

(4) (d) Hydrogen

(5) (c) Neutron

2. Answer:

(1) (a) Protons

(2) (b) Z

(3) (d) Z

(4) (c) Isobars

(5) (a) Isotopes