4 ATOMIC STRUCTURE

THEORY

4.1 INTRODUCTION

All matter is composed of tiny particles called atom. An atom is the smallest particle of an element that can exist and still have properties of an element. John Dalton in 1808 published theory of atom assuming that atoms are the ultimate indivisible particle of matter. Maharshi Kanad proposed same theory as that of Dalton and smallest particle of matter was called Anu and Parmanu. Maharshi Kanad does not got any recognition at international level.

4.2 CHARGED PARTICLES IN MATTER

Dalton assumed that atom is indivisible, i.e., it has no constituent parts. But a series of experimental evidences revealed that an atom is made up of three subatomic particles : electrons, protons and neutrons. These three particles are called fundamental particles of matter. Now, let us see how these particles were discovered.

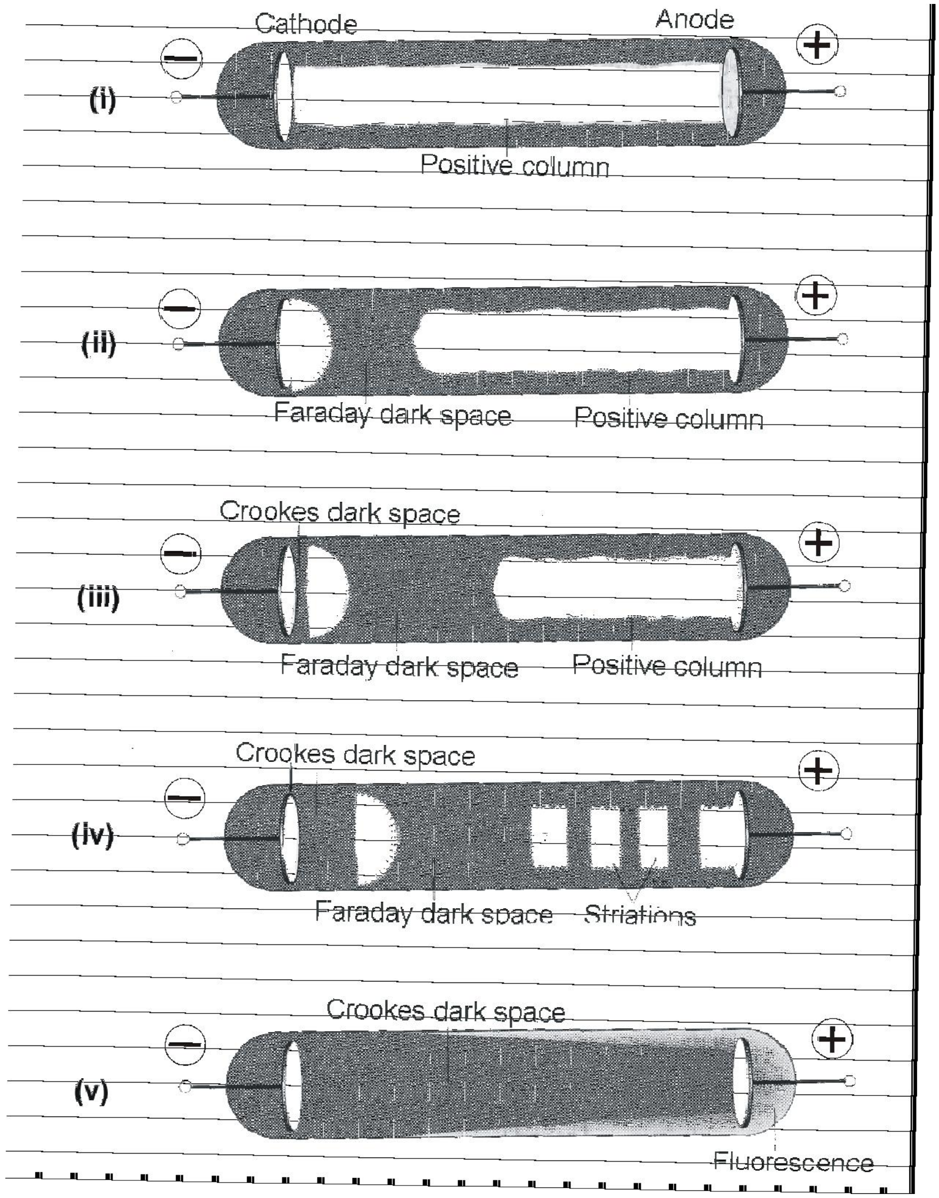
CATHODE RAY EXPERIMENT-DISCOVERY OF ELECTRON

The existence of electrons in an atom was shown by J.J. Thomson in 1897 by passing electricity at high voltage through a gas at very low pressure in a discharge tube.

A number of interesting things happen when a high voltage (say, 10,000V) is applied across the electrodes of the discharge tube, and the pressure of the gas inside the tube is lowered.

(i) when the pressure of the gas in the discharge tube is atmospheric pressure and a high voltage is applied across the electrodes, nothing noticable happens. But as we lower the pressure and/or light are seen in the tube.

(ii) As the pressure of gas is reduced further, the length of the positive column reduces and fine glow can be seen at the cathode. The dark space or gap left between the cathode and anode. The dark space or gap left between the cathode and the positive column is called Faraday's dark space.



(iii) When the pressure of gas is reduced to about 1 mm of Hg, the cathode glow moves away from the cathode, creating a dark space between cathode and the cathode glow. The dark space is called Crookes dark space.

(iv) The Crookes dark space expands with further fall in pressure to 0.1 mm of Hg. The positive column gets split into a number of bands called striations.

(v) At pressure 0.01 mm of Hg or less, the striations move towards anode and vanish finally. At this stage the glass tube begins to glow at the end opposite to the cathode this phenomenon is called **fluorescence**.

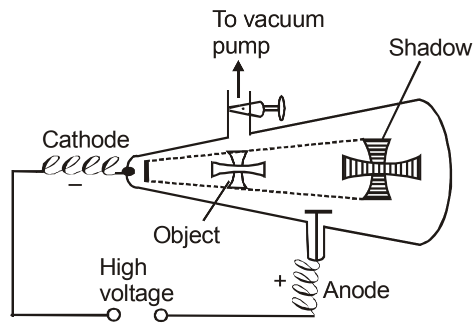
Thus, some sort of invisible rays trave from the negative electrode to the positive electrode. Since the negative electrode called cathode, these rays were called cathode rays. The colour of glow depends upon the nature of the glass used. For soda glass the fluorescence is yellowish green in colour.

❖ **Note :** William crooks was the first who conducted discharge tube experiment.

❖ **Note :** In 1859, Julius Plucker started the study of conduction of electricity through gases at low pressure in a discharge tube.

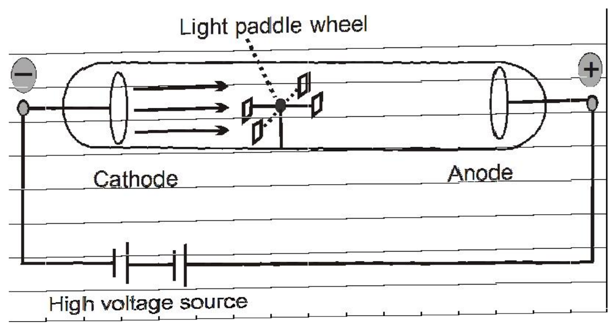
Properties of Cathode Rays :

(i) Cathode rays travel in a straight line at a high velocity and generate normally from the surface of the cathode. If an opaque object is placed in the path or cathode rays its shadow falls on opposite side of the cathode. It shows that cathode rays travel in straight lines.

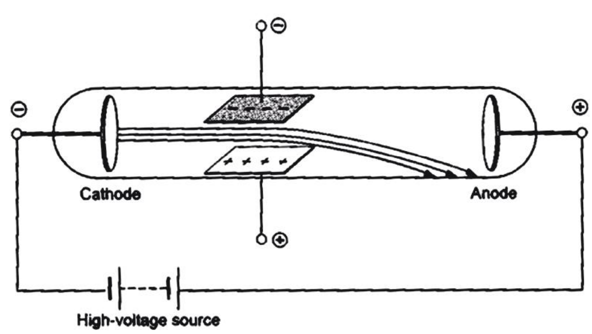


❖ **Note :** Cathode rays travel with very high velocities ranging from 10^9 to 10^{11} cm per second.

(ii) They are a beam of minute material particles having definite mass and velocity. When a light paddle is placed in the path of the cathode rays, the blades of the paddle wheel begin to rotate. This also prove that cathode rays have mechanical energy.



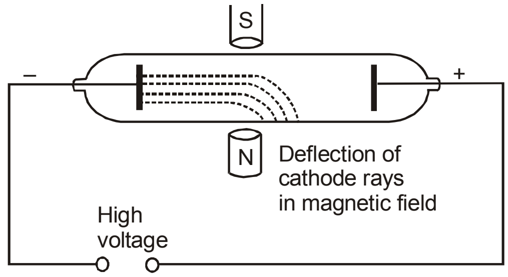
(iii) They consist of negatively charged particles. When the cathode rays pass through an electric field, they bent towards the positive plate of the electric field. This indicates that cathode rays are negative charged.



(iv) Cathode rays can affect the photographic plate.

(v) The nature of cathode rays is independent of the nature of gas used in discharge tube or material of cathode.

(vi) Cathode rays are deflected in the magnetic field also.



(viii) when cathode rays fall on materials having high atomic mass, new type of penetrating rays of very small wavelength are emitted which are called X rays.

❖ **Note :** The negatively charged particles of cathode rays were called 'negatrons' by Thomson. The name negatron was changed to 'electron' by Stoney.

Characteristics of Electron :

(i) Electrons are sub-atomic particles which constitute cathode rays.

(ii) In 1897, J.J. Thomson determined the charge to mass (e/m) ratio of electron by studying the deflections of cathode rays in electric and magnetic fields. The value of e/m has been found to be 1.7588×10^8 coulomb/g. The e/m for electrons from different gases was found to be the same. This indicates that atoms of all kinds have the same kind of negatively charged particles. Thus electrons are the common constituents of all atoms.

❖ **Note :** A cathode ray tube is used to measure the charge to mass ratio of the electrons which is 1.7588×10^8 C/g or 1.7588×10^{11} C/kg.

(iii) **Charge on the electron :** The charge (e) on an electron was determined by Robert Millikan by oil-drop method in 1909.

Charge on electron will be 1.6×10^{-19} C

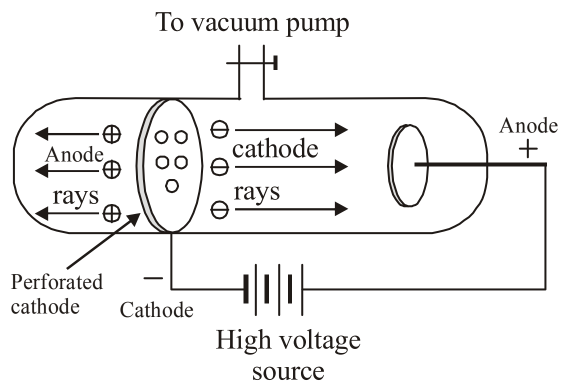
(iv) Mass of an electron 9.1×10^{-31} kg

(v) $$\frac{\text{Mass of electron}}{\text{Mass of hydrogen atom}} = \frac{9.1096 \times 10^{-28}\,\text{g}}{1.673 \times 10^{-24}\,\text{g}} = \frac{1}{1837}$$

Thus, the mass of an electron is $\frac{1}{1837}$ times the mass of a hydrogen atom.

➢ **Positive Rays-Discovery of Proton**

In 1886 Eugen Goldstein first observed that a cathode ray tube also generates a stream of positively charged particles that move towards the cathode. These were called canal rays because they were observed occasionally to pass through a channel, or "canal", drilled in the negative electrode.



(a) **E. Goldstein** in 1886 discovered proton by repeating the same discharge tube experiments by using a perforated cathode.

(b) When a high potential difference was applied, not only cathode rays were produced but also a new type of rays were produced simultaneously from anode moving towards cathode and passed through the holes of the cathode. These termed as **canal ray** or **anode ray**.

(c) These positive rays, or positive ions, are created when cathode rays knock elements from the gaseous atoms in the tube, forming positive ions by processes such as

$$\text{atom} \longrightarrow \text{cation}^+ + e^- \qquad \text{or} \qquad X \longrightarrow X^+ + e^-$$

These rays were attracted towards the negative plate in the electric field. This means that these rays consist of positively charged particles and were also named positive rays or anode rays.

(d) **Properties of cathode rays :**

(i) Travel in straight line and cast shadow

(ii) Deflected by the magnetic and electric fields

(iii) These rays have kinetic energy and produce heating effect also.

(iv) Unlike cathode rays, their e/m value is dependent upon the nature of the gas taken in the tube.

(v) These rays can pass through thin metal foils.

(vi) They are capable to produce ionization in gases.

(e) **Characteristics of Anode rays :**

(i) **e/m value of proton :**

e/m value of proton was different for different gases taken in cathode ray tube (CRT). Value of e/m of proton is lower for hydrogen gas.

(ii) **Charge of proton:** Charge of proton is $+1.6022 \times 10^{-19}$ coulomb.

(iii) **Mass of proton:** Mass of proton was found to be 1.66×10^{-24} gm $= 1.66 \times 10^{-27}$ kg $= 1.0072$ amu.

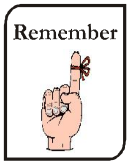


Illustration 1

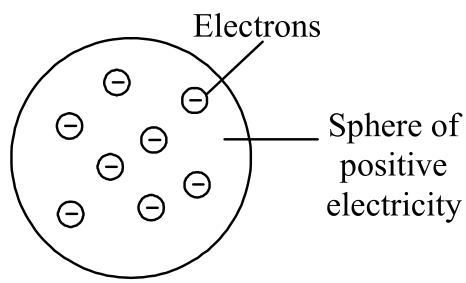
What is the difference in the origin of cathode rays and anode rays?

Solution

Cathode rays originate from the cathode whereas anode rays are not produced from the anode. They are produced from the gaseous atoms by knock out of the electrons by high speed cathode rays.

4.3 THOMSON ATOMIC MODEL(THE RAISIN PUDDING MODEL) (PLUM PUDDING MODEL): FIRST ATOMIC MODEL

Thomson concluded that there must be an equal amount of positive charge present in an atom. On the basis he proposed a model of the structure of atom. According to his model, atoms can be considered as a large sphere of uniform positive charge with a number of small negatively charged electrons scattered throughout it. This model was called as plum pudding model. The electrons present the plums in the pudding made of negative charge. This model is similar to a watermelon in which the pulp represents the positive charge and the seeds denote the electrons.

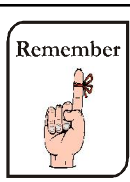


LIMITATIONS

Thomson's model of an atom could explain the main characteristics of the atom at that time. But it did not have any experimental support. Therefore, it was opposed by his co-scientists and was rejected. Rutherford scattering experiment raised an objection against the model.

ACCEPTANCE

The prediction that an atom is electrically neutral and has no net charge, is still accepted. This was indeed a big contribution towards the structure of the atom.

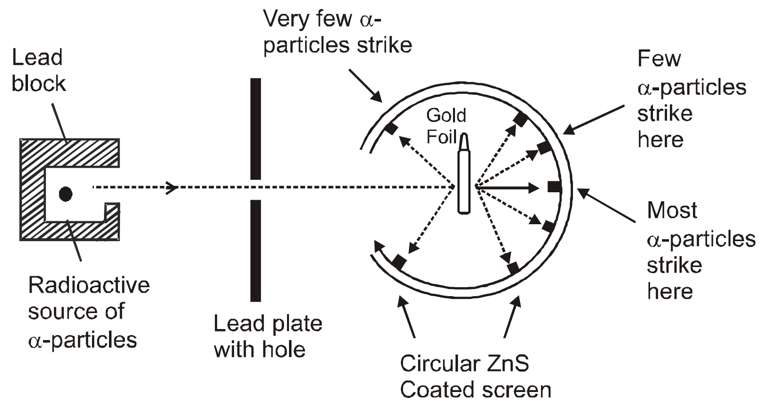


This model is compared with a water melon in which seeds are embedded or with a cake or pudding in which raisins (dried grapes) are embedded. That is why this model is sometimes called raisin pudding model or watermelon model

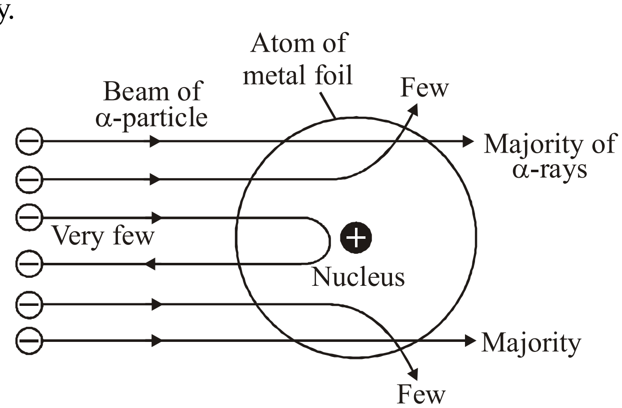
4.4 RUTHERFORD MODEL OF AN ATOM

➢ **ALPHA PARTICLE SCATTERING EXPERIMENT:**

Rutherford in 1911 designed an experiment. In this experiment, a fast moving α-particle is made to fall on a thin gold foil.



He took gold foil that was about 100 nm or 10^{-5} cm thick.by α-particle. α-particle are +2 charged helium ions. Since they have mass of 4u, the fast moving α-particle have a considerable amount of energy.



Scattering of α-particles by a gold foil :

The α-particle scattering experiment gave totally unexpected result. It has following observations:-

(i) Most of the fast moving α-particles (99% nearly) passed straight through the gold foil.

(ii) Some of them were deflected by small angles.

(iii) A very few α-particles (1 in 20000) were either deflected by very large angle or were actually reflected back along their path.

Rutherford gave following conclusion :

(i) Since most of the α-particles pass through the foil undeflected, it indicates that the most of the space in an atom is empty.

(ii) α-particle being positively charged and having considerable mass could be deflected only by some heavy, positively charge centre. The small angle of deflection of α-particles indicated the presence of a heavy positively charged centre in the atom. Rutherford named this positive centre as nucleus.

(iii) α-particle which makes head-on collision with heavy positive centre are deflected through large angles. Since the number of such α-particles is very small the space occupied by the heavy positive centre must be very small.

RUTHERFORD'S NUCLEAR MODEL OF ATOM:

(i) Most of the mass and all the positive charges of an atom is concentrated in a very small region called nucleus. Size of nucleus is extremely small as compared with the size of the atom. Radius of the nucleus is of the order of 10^{-15} m, whereas radius of atoms is of the order of 10^{-10}m.

(ii) The positive charge on the nucleus is due to protons. The magnitude of the charge on the nucleus is different for atoms of different elements.

(iii) The nucleus is surrounding by electrons which are revolving around it at very high speeds in circular paths called orbits.

(iv) Total negative charges on the electron is equal to the total positive charge on the nucleus so that atom on the whole is electrically neutral.

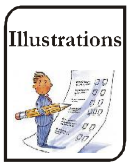


Illustration 2

Why Rutherford's model of atom is also called planetary model of atom?

Solution :

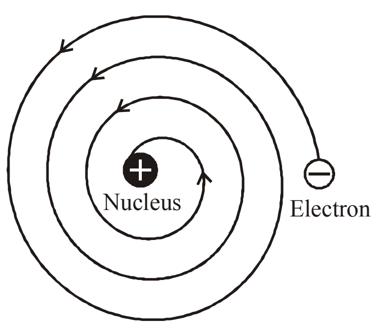
This model of atom is similar to our solar system where the nucleus is like the sun and the electrons, are like the planets. That is why these electrons are also called planetary electrons.

➢ **Drawbacks of Rutherford's model**

Rutherford's model was challenged by Maxwell on the basis of **radiation theory**. According to this, charged particles moving in circular orbits with fast speed emit energy in the form of radiations. Since electrons are also fast moving charged particles, they must release energy continuously in the form of radiations. With reduced energy, they must be drawn closer to the nucleus. Since the loss of energy is a continuous process, the electrons must come closer and closer to the nucleus of the atom. Ultimately, they must fall into the nucleus or become its part. However, this does not actually happen. The size of the atom remains the same although the electrons are moving in a circular path as stated earlier. Rutherford could not give a suitable explanation for this. It may therefore, be regarded as the major drawback or limitation of the Rutherford Model of atom. There are infact, two main limitations of Rutherford Model atom.

(i) Rutherford model of atom could not explain the stability of the atom.

(ii) Rutherford model of atom could not explain as to how the electrons are distributed in the extra nuclear portion in an atom.



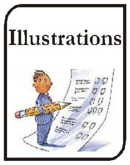


Illustration 3

What is ratio of mass of proton and electron?

Solution

$$\frac{1.67\times10^{-27}\,\text{Kg}}{9.1\times10^{-31}\,\text{Kg}} = 1837$$

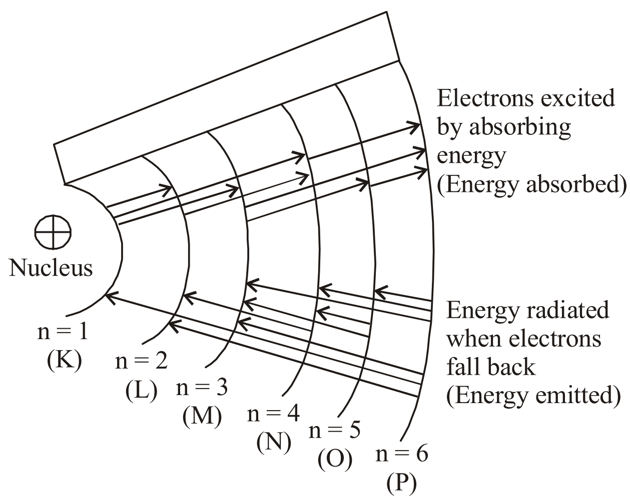
4.5 BOHR MODEL OF AN ATOM (1913)

To overcome the objections to Rutherfords' model and to explain the hydrogen spectrum, Bohr proposed a quantum mechanical model of the atom.

The important postulates on which Bohr's model is based are following

(i) The atom has a nucleus where all the protons are present. The size of the nucleus is very small. It is present at the centre of the atom.

(ii) Each stationary orbit is associated with a definite amount of energy. The greater is distance of the orbit from the nucleus, more shall be the energy associated with it. These orbits are also called energy levels and are numbered as 1, 2, 3, 4, ... or K, L, M, N ...... from nucleus to outwards.



(iii) By the time the electron remains in any one of the stationary orbits, it does not lose energy. Such a stage is called ground or normal state.

(iv) The emission or absorption of energy in the form of radiation can only occur when an electron jumps from one stationary orbit to another.

$$\Delta E = E_{final} - E_{initial} = h\nu$$

Where h is Planks constant h = 6.625×10^{-34} Js.

Energy is absorbed when the electron moves from lower to higher orbit and is emitted when it jump from higher to lower orbit.

When the electron moves from inner to outer orbit by absorbing definite amount of energy, the new state of the electron is said to be excited state.

(v) Negatively charged electrons are revolving around the nucleus in the same way as the planets are revolving around the sun. The path of the electron is circular. The force of attraction between the nucleus and the electron is equal to centrifugal force of the moving electron.

$$\frac{KZe^2}{r^2} = \frac{mv^2}{r}$$

(vi) Out of definite number of possible circular orbits around the nucleus, the electron can revolve only in those orbits whose angular momentum is an integral multiple of $\frac{h}{2\pi}$, i.e., $mvr = n\frac{h}{2\pi}$ where m = mass of the electron, v = velocity of the electron, r = radius of the orbit and n = 1, 2, 3 .... number of orbit. The angular momentum can have values such as $\frac{h}{2\pi}, \frac{2h}{2\pi}, \frac{3h}{2\pi}$, but it cannot have a fractional value. Thus, the angular momentum is quantized. the specified circular orbits (quantized) are called stationary orbits.

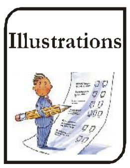


Illustration 4

Why are Bohr's orbits called stationary states?

Solution

This is because the energies of the orbits in which the electrons revolve are fixed.

- **Success of Bohr's Model**
  - **(i) It explains the stability of the atoms :** According to Bohr's theory, an electron cannot lose energy as long as it stays in a particular orbit.
  - **(ii) It explains the line spectrum of hydrogen :** The most remarkable success of the Bohr's theory is that it provides a satisfactory explanation for the line spectrum of hydrogen.
  - (iii) Bohr's theory helped in calculating energy of an electron in a particular orbit of hydrogen.
- **Failures/Limitations of Bohr's Theory**
  - (i) It was failed to explain spectra of atom having 2 or more than 2 electrons (multielectronic species).
  - (ii) It was failed in explaining the splitting of spectral lines under the influence of magnetic field (Zeeman effect) and electric field (Stark effect).
  - (iii) Bohr model of atom was planar model. It failed in explaining 3-D view or look of atom.
  - (iv) It failed in accounting for Heisenberg uncertainty principle and de-Broglie concept.

NEUTRON

- **Discovery of Neutron**

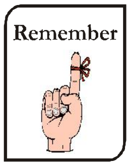
  So far we have studied by Rutherford's atomic model that the mass of the atom is mainly due to the protons and it is concentrated in the nucleus. Chadwick (1932), while studying the bombardment of light elements, such as beryllium, boron and lithium, by fast moving α-particles obtained highly penetrating radiations. These radiations were found to have high ionising power and were not deflected by electric or magnetic field. Hence these are neutral in nature. These neutral particles were found to have mass 1.675×10^{-24} g and were named neutrons.

The reactions responsible for the production of neutron were later found to be

(i) $${}^{9}_{4}Be + \underset{(\alpha-\text{particle})}{{}^{4}_{2}He^{+2}} \longrightarrow {}^{12}_{6}C + \underset{(\text{Neutron})}{{}^{1}_{0}n}$$

(ii) $${}^{11}_{5}B + {}^{4}_{2}He^{+2} \longrightarrow {}^{14}_{7}N + {}^{1}_{0}n$$

Thus, a neutron is defined as a sub-atomic particle which has mass almost equal to that of a proton (1.675×10^{-27} kg) but has no charge.



This discovery led to the modification of Rutherford atomic model. In the modified atomic model the nucleus consists of protons and neutrons and these are collectively termed as nucleons. The entire mass of the atom is due to the number of nucleons present in the atom.

Properties of Fundamental of Particles of Atoms

Particles	Symbol	Relative Charge	Absolute Charge (C)	Mass (kg)	Mass u
Electron	e	– 1	-1.6022×10^{-19}	9.10939×10^{-31}	0.00054
Proton	p	1	$+1.6022 \times 10^{-19}$	1.6726×10^{-27}	1.00727
Neutron	n	0	0	1.67493×10^{-27}	1.00867

4.6 ATOMIC NUMBER

In 1913, H.G.J. Mosely discovered concept of atomic number.

The number of unit positive charge on the nucleus of an atom of the element is called atomic number of the elements. It is denoted by the letter Z.

Atomic number of an element (Z) = Number of protons present in an atom of element.

The atomic number of sodium is 11, so we can say that for sodium Z = 11.

All the atoms of the same element have the same number of protons in their nuclei and hence they have the same atomic number. No two elements can have the same atomic number. Therefore atomic number can be used to identify an element.

In a neutral atom the number of protons is equal to the number of electrons in it. So, we can also say that the atomic number of an element is equal to the number of electrons in a neutral atom of that element.

Atomic number of an elements = Number of electrons in one neutral atom.

Only electrons of an atom take part in chemical reaction, the proton do not take part in a chemical reaction. Thus, the atomic number of an element does not change during a chemical reaction.

4.7 MASS NUMBER

Total number of protons and neutrons in the nucleus is called mass number of the atom. It is generally denoted by letter A.

> Mass Number (A) = Number of protons + Number of neutrons
> Mass Number (A) = Number of nucleons
> Mass number = Atomic mass

4.8 REPRESENTATION OF ATOMIC NUMBER AND MASS NUMBER OF AN ELEMENTS

The atomic number is written on the lower left side of the symbol whereas mass number is written on the upper left side of the symbol of the element.

Mass Number
Atomic Number **Symbol of element**

For example, an atom of nitrogen whose atomic number is 7 and mass number is 14 is represented as

$$^{14}_{7}N$$

4.9 APPLICATION OF ATOMIC NUMBER AND MASS NUMBER:

With the help of atomic number and mass number, number of electrons, protons and neutrons can be calculated in atom or ions.

$\boxed{\text{Number of neutrons} = A - Z}$

$\boxed{\text{Number of Protons} = Z}$

Calculation of number of electron:

For neutral atom $\boxed{\text{Number of Electrons} = Z}$

For cation $\boxed{\text{Number of Electrons} = Z - \text{charge on cation}}$

For Anion $\boxed{\text{Number of Electrons} = Z + \text{charge on Anion}}$

Remember

A shorthand notation has been developed to describe the number of neutrons and protons in the nucleus of an atom. The atomic number is written in the bottom left corner of the symbol for the element and the mass number is written in the top left corner : $^{A}_{Z}X$. The atoms in figure would therefore be given the symbol $^{12}_{6}C$ and $^{23}_{11}Na$.

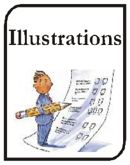


Illustration 5

How many protons, electrons and neutrons are present in $^{30}_{15}P$?

Solution

Number of protons in one atom of Proton = Number of electrons in one atom of proton = 15

Number of neutrons in one atom of P = (A–Z) = 30–15 = 15

Illustration 6

Calculate the number of protons, neutrons and electrons in $^{80}_{35}\mathbf{Br}$.

Solution

Here, $Z = 35, A = 80$

$\therefore$ No. of protons = Atomic Number = 35

No. of neutrons = A – Z = 80 – 35 = 45

As the atom is neutral, No. of electrons = No. of protons = 35.

Illustration 7

Calculate the number of electron, protons and neutrons, in $^{31}_{15}P^{-3}$.

Solution

Here Z = 15 A = 31

Number of protons = Z = 15

Number of neutrons = A – Z = 31 – 15 = 16

Number of electrons for anions = Z + charge on anion = 15 + 3 = 18

4.10 VALENCE ELECTRONS AND VALENCY

Valence electrons: The electrons in the outermost shell of an atom are called its valence electrons (valency) because they decide the valency (combining capacity) of the atom. For example, the number of valence electron in sodium is one, the number of valence electrons in chlorine is seven.

How can the electronic configuration of an element explain its chemical reactivity

The elements having a completely filled outermost orbit (or shell) will be chemically inert (non-reactive). These elements do not form compounds with other elements

Element	Total number of electrons	Distribution of electrons in various shells		
		K	L	M
He	2	2		
Ne	10	2	8	
Ar	18	2	8	8

Because of this chemical inactivity, these gases are called **noble gases** (earlier these were called inert gases.

Completely filled outermost shell provide stability. The atoms combine with one another to achieve the inert gas electron arrangement and become more stable.
An atom can achieve the inert gas (or noble gas) electron arrangement in three ways:
(i) by losing one or more electrons (to another atom)
(ii) by gaining one or more electrons (from another atom)
(iii) by sharing one or more electrons (with another atom)

If an element has 1, 2 or 3 electrons in the outermost shell of its atom, then it loses these electrons to achieve the inert gas electron arrangement of eight valence electrons and forms positively chraged ion or cation. (It is not possible to add 7, 6, or 5 electrons to an atom due to energy consideration.
If an element has 5, 6 or 7 electrons in the outermost shell of its atom, then it gains electrons to achieve the inert gas configuration of eight valence electrons, and forms negatively charged ion called anion. It is not possible to remove (5, 6 or 7 electrons from an atom due to very high energy required.)
If, however an element has 4 electrons in the outermost shell of its atom, then it can neither lose 4 electrons nor gain 4 electrons due to energy consideration. An element having 4 electrons in the outermost shell of its atom can achieve the inert gas electron arrangement of eight valence electrons only by sharing its 4 outermost electrons with 4 electrons of the other atoms.

The elements containing only one, or seven electrons in their outermost shell show greater chemical reactivity, i.e., such elements react very fast with other elements. For example, sodium and chlorine having the follwing electronic configurations are highly reactive.

- Sodium 2, 8, 1 - Here, the outermost shell has only one electron: one more than the completely filled shell.
- Chlorine 2, 8, 7 - Here, the outermost shell has seven electrons: one less than that required to fill the shell completely.

➢ **Ion Formation**

The atomic number of sodium (Na) is 11. Its electronic configuration is 2, 8, 1. Na^+ ion is obtained when one electron is lost from sodium atom.
So, the electronic configuration of Na^+ is 2,8. The electronic configuration 2,8 is the electronic configuration of neon (Ne). Thus, Na^+ resembles neon (Ne) in its electronic configuration

$$\underset{2,8,1}{Na} \longrightarrow \underset{2,8}{Na^+} + \underset{\text{electron}}{e^-}$$

The atomic number of chlorine (Cl) is 17. Its electronic configuration is 2, 8, 7. Cl^- ion is obtained when one electron is gain from chlorine atom.
So, the electronic configuration of Cl^- is 2, 8, 8. The electronic configuration 2, 8, 8 is the electronic configuration of argon (Ar). Thus, Cl^- resembles argon (Ar) in its electronic configuration.

$$\underset{2,8,7}{Cl} + e^- \longrightarrow \underset{2,8,8}{Cl^-}$$

4.11 VALENCY OF ELEMENTS

Valency of elements tells about its combining capacity. The capacity of an atom of an element to form chemical bonds V known as its valency. The valency of an element is decided by the number of valence electrons in its atom.

The valency of an element is either equal to the number of valence electron in its atom or equal to the number of electrons required to complete eight electrons in the valence shell.

Generally

$$\boxed{\text{Valency of a metal = Number of valence electrons in its atom}}$$

$$\boxed{\text{Valency of a non metal = 8 – Number of valence electrons in its atom}}$$

There are two types of valency: Electrovalency and covalency.

Electrovalency: In the formation of an electrovalent compound (or ionic compound) the number of electrons lost or gained by one atom of an element to achieve the nearest inert gas configuration is known as its electrovalency.

Covalency: In the formation of a covalent compound (or molecular compound) the number of electrons shared by one atom of an element to achieve the nearest inert gas configuration is known as its covalency.

ADVANCE CONCEPT OF ATOMIC STRUCTURE

4.12 ATOMIC STRUCTURE

An atom consists of two parts -

(a) Nucleus (b) Extra - nuclear region

Nucleus :

Nucleus is situated at the centre of an atom. All the protons & neutrons are situated in the nucleus, therefore, the entire mass of an atom is almost concentrated in the nucleus. The overall charge of nucleus is positive due to the presence of positively charged protons (neutrons have no charge). The protons & neutrons are collectively called nucleons.

❖ **Note :**

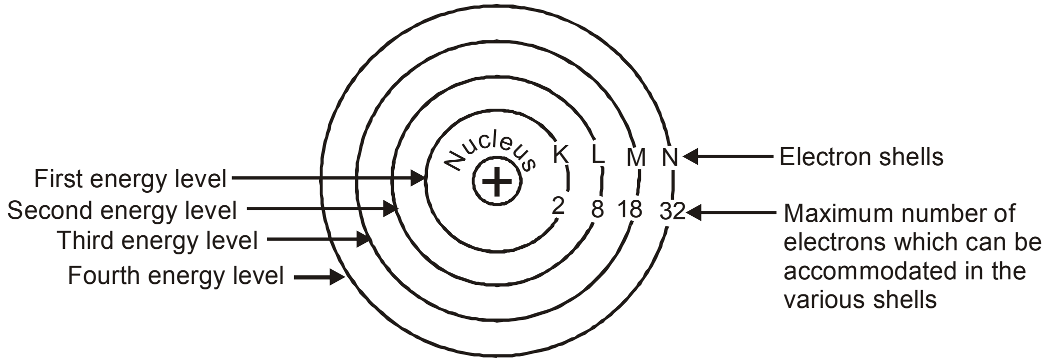
The radius of the nucleus of an atom is of the order of 10^{-13} cm and its density is of the order of 10^{14} g/cm^3.

Extra Nuclear Region :

In extra nuclear part or in the region outside the nucleus, electrons are present which revolve around the nucleus in orbits of fixed energies. These orbits are called energy levels. These energy levels are designated as K, L, M, N & so on.

(i) The maximum number of electrons that can be accommodated in a shell is given by the formula $2n^2$.(n = shell number i.e. 1,2,3 -------)

Shell	n	$2n^2$	max. no.of electrons
K	1	$2(1)^2$	2
L	2	$2(2)^2$	8
M	3	$2(3)^2$	18
N	4	$2(4)^2$	32



(ii) Each energy level is further divided into subshells designated as s,p,d,f .
1st shell (K) contains 1 subshell (s)
2nd shell (L) contains 2 subshells (s,p)
3rd shell (M) contains 3 subshells (s,p,d)
4th shell (N) contains 4 subshells (s,p,d,f).

(iii) Shells are divided into sub-shells, sub shells further contain orbitals.

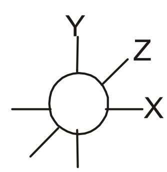
(a) An orbital may be defined as
"A region in the three - dimensional space around the nucleus where the probability of finding the electron is maximum."

(b) The maximum capacity of each orbital is that of two electrons.

❖ **Note :** The maximum number of orbitals that can be present in a shell is given by the formula n^2.

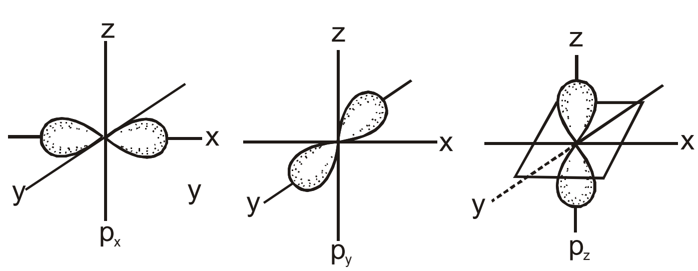
(c) Types of orbitals :

(1) s-orbitals : The s-subshell contains just one orbital which is non-directional & spherically symmetrical in shape. The maximum number of electrons which can be accommodated in s-orbital is **2**.

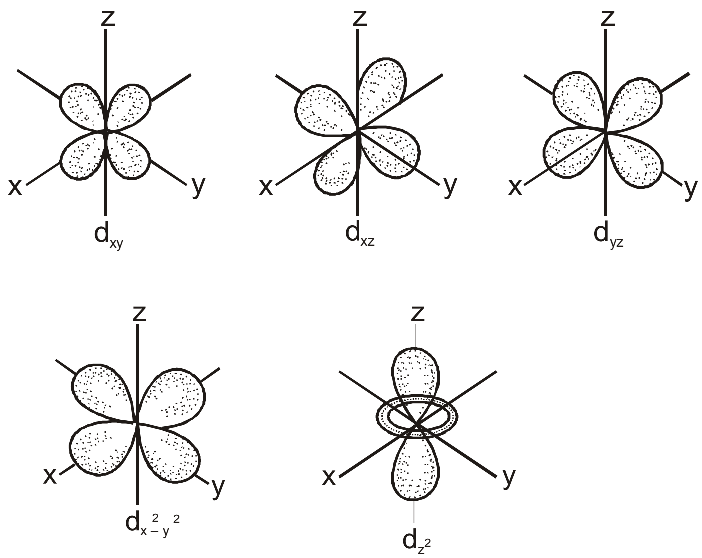


s- orbital

(2) p - orbitals : The p-subshell contains three orbitals which have dumb-bell shape and a directional character. The three p-orbitals are designated as p_x, p_y & p_z which are oriented in the perpendicular axis (x,y,z). The maximum number of electrons which can be accommodated in the p subshell is 6 (2 electrons in each of three orbitals).



(3) d-orbitals : The d-subshells contains 5 orbitals which are double dumb-bell in shape. These orbitals are designated as d_{xz}, d_{xy}, d_{yz}, $d_{x^2-y^2}$, d_{z^2}. The d-subshell can accommodate a maximum of 10 electrons.



(4) f-orbitals : The f-subshell contains 7 orbitals which are complex in structure. The f-subshell can accommodate a maximum of 14 electrons.

❖ **Note :** Letters s, p, d & f have originated from the words sharp, principal, diffused & fundamental respectively.

(iv) Differences between orbit and orbital :

S.No.	Orbit	Orbital
1	It is well defined circular path around the nucleus in which the electron revolves.	It is a region in three dimensional space around the nucleus where the probability of finding electron is maximum.
2	It is circular in shape.	s,p and d-orbitals are spherical, dumb-bell and double dumb-bell in shape respectively.
3	It represents that an electron moves around the nucleus in one plane.	It represents that an electron can move around nucleus along three dimensional space (x,y and z axis).
4	It represents that position as well as momentum of an electron can be known simultaneously with certainty. It is against Heisenberg's uncertainty principle.	It represents that position as well as momentum of an electron cannot be known simultaneously with certainty. It is in accordance with Heisenberg's uncertainty principle.
5	The maximum number of electrons in an orbit is $2n^2$ where 'n' is the number of the orbit.	The maximum number of electrons in an orbital is two.

4.13 QUANTUM NUMBERS

To describe the position and energy of electron in an atom, four numbers are required, which are known as quantum numbers.

Four quantum numbers are :

(a) Principal quantum number (b) Azimuthal quantum number

(c) Magnetic quantum number (d) Spin quantum number

Principal Quantum Number :

(i) It is denoted by 'n'.

(ii) It represents the name, size and energy of the orbit or shell to which the electron belongs.

(iii) Higher is the value of 'n' , greater is the distance of the shell from the nucleus.

$r_1 < r_2 < r_3 < r_4 < r_5 <$ ----

(iv) Higher is the value of 'n', greater is the magnitude of energy.

$E_1 < E_2 < E_3 < E_4 < E_5$ ----

(v) Maximum number of electrons in a shell is given by $2n^2$.

Shell	Max. number of electrons
First (n =1)	$2 \times 1^2 = 2$
Second (n = 2)	$2 \times 2^2 = 8$
Third (n = 3)	$2 \times 3^2 = 18$
Fourth (n = 4)	$2 \times 4^2 = 32$

(vi) Angular momentum can also be calculated using principal quantum number.

$$mvr = \frac{nh}{2\pi}$$

(vii) Value of n is from 1 to ∞

(viii) Every shell is given a specific alphabetic name.
First shell (n = 1) is known as K shell.
Second shell (n = 2) is known as L shell.
Third shell (n = 3) is known as M shell and so on.

❖ **Note :** Principal quantum number was given by Bohr.

Azimuthal Quantum Number :

(i) It is represented by 'ℓ'.

(ii) For a given value of n values of ℓ are from 0 to n – 1

Value of n	Values of ℓ
1 (1st shell)	0
2 (2nd shell)	0,1
3 (3rd shell)	0,1,2
4 (4th shell)	0,1,2,3

(iii) It represents the sub-shell present in shell.
$\ell = 0$ represents s sub shell.
$\ell = 1$ represents p sub shell.
$\ell = 2$ represents d sub shell.
$\ell = 3$ represents f sub shell.

(iv) Number of sub-shell in a shell = Principal quantum number of shell.

(v) Maximum value of ℓ is always less than the value of n. So 1p, 1f, 2d, 2f, 3f subshells are not possible.
s will start from 1s
p will start from 2p
d will start from 3d
f will start from 4f

(vi) Relative energy of various sub-shell in a shell are as follows -
$s < p < d < f$

(vii) Subshells having equal ℓ values but with different n values have similar shapes but their sizes increases as the value of 'n' increases. 2s-subshell is greater in size than 1s- subshell. Similarly 2p, 3p, 4p subshells have similar shapes but their sizes increase in order $2p < 3p < 4p$.

(viii) Maximum no. of electrons present in a subshell = $2(2\ell+1)$

Subshell	**Max. electrons**
s ($\ell = 0$)	$2(2 \times 0 + 1) = 2$
p ($\ell = 1$)	$2(2 \times 1 + 1) = 6$
d ($\ell = 2$)	$2(2 \times 2 + 1) = 10$
f ($\ell = 3$)	$2(2 \times 3 + 1) = 14$

❖ **Note :** Azimuthal quantum number is also called angular quantum number, subsidiary quantum number or secondary quantum number.

❖ **Note :** Azimuthal quantum number was given by Sommerfeld.

(c) Magnetic quantum number :

(i) It is denoted by 'm'.

(ii) It represents the orbitals present in sub-shell.

(iii) For a given value of ℓ, values of m are from $-\ell$ through 0 to $+\ell$.

ℓ	**m**
0	0
1	–1, 0, +1
2	–2, –1, 0, +1, +2
3	–3, –2, –1, 0, +1, +2, +3

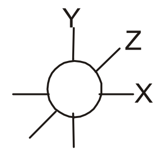
(iv) Maximum number of orbitals in a sub-shell= $(2\ell+1)$

Sub shell	**Orbitals**
s ($\ell = 0$)	$(2 \times 0 + 1) = 1$
p ($\ell = 1$)	$(2 \times 1 + 1) = 3$
d ($\ell = 2$)	$(2 \times 2 + 1) = 5$
f ($\ell = 3$)	$(2 \times 3 + 1) = 7$

(v) Maximum number of orbitals in a shell = n^2

Shell	**Max. orbitals**
First (n = 1)	$1^2 = 1$
Second (n = 2)	$2^2 = 4$
Third (n = 3)	$3^2 = 9$
Fourth (n = 4)	$4^2 = 16$

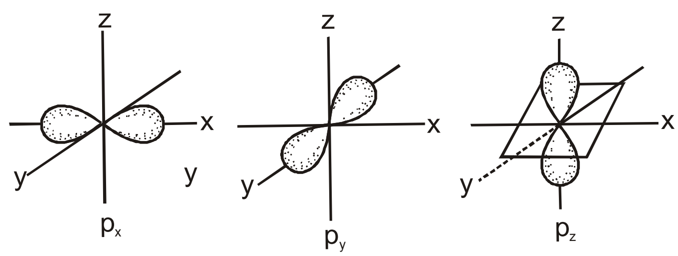
(vi) It represents the orientation of orbital in three dimensional space.
When $\ell = 0$, m = 0, i.e. one value implies that 's' subshell has only one space orientation and hence, it can be arranged in space only in one way along x,y or z axis. Thus, 's' orbital has a symmetrical spherical shape.



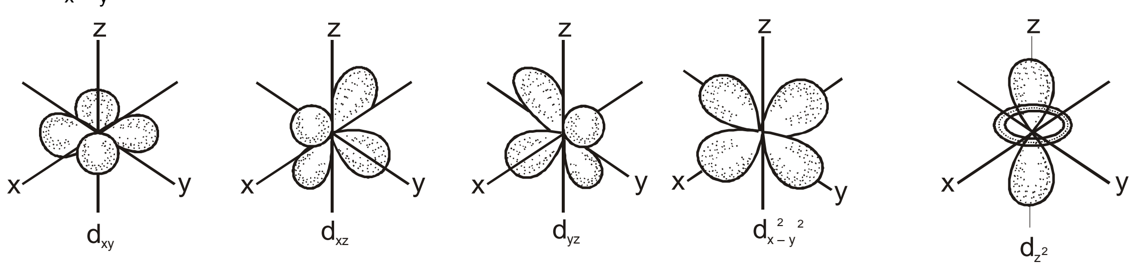
s- orbital

When $\ell = 1$,'m' has three values –1, 0, +1 . It implies that 'p' subshell of any energy shell has three space orientations, i.e. three orbitals. Each p-orbital has dumb-bell shape. Each one is disposed symmetrically along one of the three axis. p orbitals have directional character.

orbital	P_z	P_x	P_y
m	0	±1	± 1



When $\ell = 2$ 'm' has five values –2, –1, 0, +1, +2. It implies that d-subshell of any energy shell has five orientations, i.e. five orbitals. All the five orbitals are not identical in shape. Four of the d-orbitals d_{xy}, d_{yz}, d_{zx}, $d_{x^2-y^2}$ contain four lobes while fifth orbital d_{z^2} consists of only two lobes.



There are seven f-orbitals designated as $f_{yz^2}, f_{xz^2}, f_{z^3}, f_{x(x^2-y^2)}, f_{y(x^2-y^2)}, f_{z(x^2-y^2)}$, and f_{xyz} . Their shapes are complicated ones.

(vii) Characteristics of orbitals :

(a) All orbitals of a subshell possess same energy i.e., they are degenerate.

(b) All orbitals of the same shell differ in the direction of their space orientation.

(c) Total number of orbitals in a shell is equal to n^2.

❖ **Note :** Magnetic quantum number was given by Zeeman.

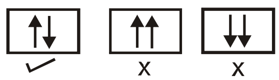
Spin Quantum Number :

(i) It is denoted by 's'.

(ii) It represents the direction of spin of electron around its own axis.

(iii) Clockwise spin is represented by +1/2 or ↑ and anticlockwise by –1/2 or ↓.

(iv) Maximum two electrons with opposite spin can be placed in an orbital.



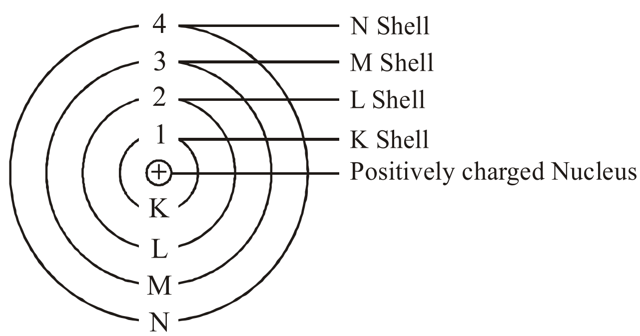
(v) Electrons with same spin are called spin parallel and those with opposite spin are called spin paired.

❖ **Note :** Spin quantum number was given by Gold Schmidt.

4.14 ARRANGEMENT OF ELECTRONS IN AN ATOM-[BOHR-BURY RULE]

➤ **Bohr-Bury scheme of electronic configuration :**

(i) The maximum number of electrons which can be present in any shell of an atom is given by the formula $2n^2$, where n is the number of shells as counted from the nucleus.



Thus, according to this scheme the distribution of the electrons in the different shells in shown in the table given below:

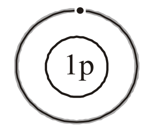
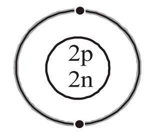
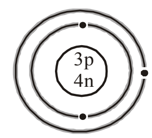
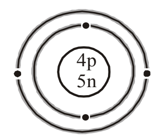
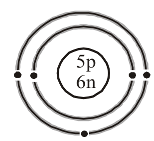
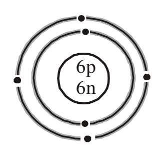
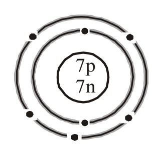
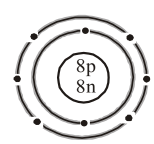
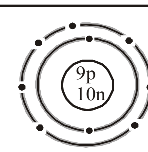
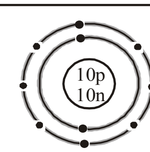
Shell number of energy level	**Maximum number of electrons**
First shell or K-shell	$2(n)^2 = 2\ (1)^2 = 2$
Second shell or L-shell	$2(n)^2 = 2\ (2)^2 = 8$
Third shell or M-shell	$2(n)^2 = 2\ (3)^2 = 18$
Fourth shell or N-shell	$2(n)^2 = 2\ (4)^2 = 32$

(ii) The outermost shell (also called valence shell) cannot have more than 8 electrons and the shell next to it cannot have more than 18 electrons. However, the outermost shell of an atom is the first shell or K shell, then it can not accommodate more than 2 electrons.

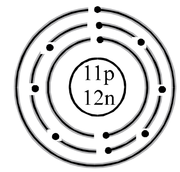
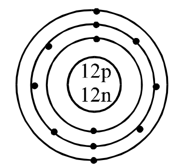
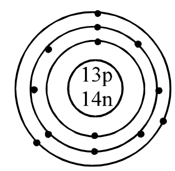
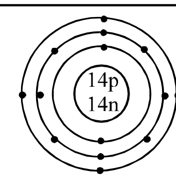
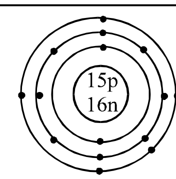
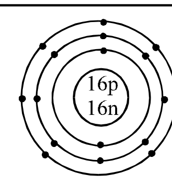
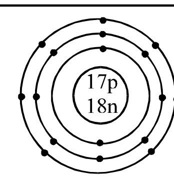
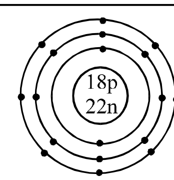
(iii) It is not necessary for a given shell to complete itself, before another shell starts forming. As a rule, new shell is formed as soon as the shell attains 8 electrons.

(iv) An atom becomes stable (i.e. it stops reacting with other elements), when its outermost shell has 8 electrons or it has only one shell containing 2 electrons.

Electronic Configuration of First 18 Elements

Element $^{A}_{Z}X$	Number of			Electronic Configuration in shells	Representation
	Electrons (Z)	Protons (Z)	Neutrons (A-Z)		
Hydrogen $^{1}_{1}\mathbf{H}$	1	1	1 – 1 = 0	K 1	
Helium $^{4}_{2}\mathbf{He}$	2	2	4 – 2 = 2	K 2	
Lithium $^{7}_{3}\mathbf{Li}$	3	3	7 – 3 = 4	K L 2, 1	
Beryllium $^{9}_{4}\mathbf{Be}$	4	4	9 – 4 = 5	K L 2, 2	
Boron $^{11}_{5}\mathbf{B}$	5	5	11 – 5 = 6	K L 2, 3	
Carbon $^{12}_{6}\mathbf{C}$	6	6	12 – 6 = 6	K L 2, 4	
Nitrogen $^{14}_{7}\mathbf{N}$	7	7	14 – 7 = 7	K L 2, 5	
Oxygen $^{16}_{8}\mathbf{O}$	8	8	16 – 8 = 8	K L 2, 6	
Fluorine $^{19}_{9}\mathbf{F}$	9	9	19 – 9 = 10	K L 2, 7	
Neon $^{20}_{10}\mathbf{Ne}$	10	10	20 – 10 = 10	K L 2, 8	

Electronic Configuration of First 18 Elements

Element $^{A}_{Z}X$	Number of			Electronic Configuration in shells	Representation
	Electrons (Z)	Protons (Z)	Neutrons (A-Z)		
Sodium $^{23}_{11}Na$	11	11	23 – 11 = 12	K L M 2, 8 1	
Magnesium $^{24}_{12}Mg$	12	12	24 – 12 = 12	K L M 2, 8, 2	
Aluminium $^{27}_{13}Al$	13	13	27 – 13 = 14	K L M 2, 8, 3	
Silicon $^{28}_{14}Si$	14	14	28 – 14 = 14	K L M 2, 8, 4	
Phosphorus $^{31}_{15}P$	15	15	31 – 15 = 16	K L M 2, 8, 5	
Sulphur $^{32}_{16}S$	16	16	32 – 16 = 16	K L M 2, 8, 6	
Chlorine $^{35}_{17}Cl$	17	17	35 – 17 = 18	K L M 2, 8, 7	
Argon $^{40}_{18}Ar$	18	18	40 – 18 = 22	K L M 2, 8, 8	

4.15 RULES FOR FILLING OF ORBITALS IN AN ATOM :

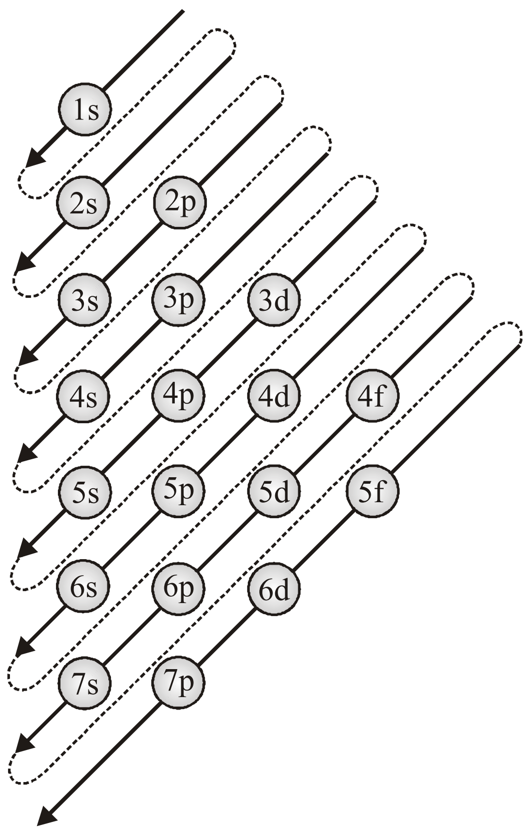
The filling of orbitals in the ground state is determined by the following values :

(1) AUFBAU PRINCIPLE

(a) It is a German word, meaning 'building up'

(b) According to this principle, "In the ground state, the atomic orbitals are filled in order of increasing energies", i.e. in the ground state the electrons occupy the lowest orbitals available to them.

(c) In fact the energy of an orbital is determined by the quantum number n and l with the help of $(n + l)$ rule or Bohr Bury rule.



(2) PAULI'S EXCLUSION PRINCIPLE

According this principle, "no two electrons in an atom can have all the four quantum numbers n, l, m and s identical.

(a) An orbital cannot have more than two electrons.

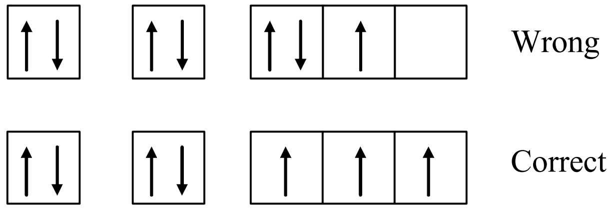
(b) If an orbital has two electrons, they must have opposite spin i.e., they must be paired electrons.

(3) HUND'S RULE OF MAXIMUM MULTIPLICITY

(a) This rule governs the filling up of degenerate orbitals of the same sub-shell.

(b) According to this rule "As far as possible electron in the degenerate orbitals remain single, pairing will not take place unless and untill each degenerate (equal energy) orbital has got a single electron.

$_7N \rightarrow 1s^2, 2s^2, 2p^3$



$1s^2 \quad 2s^2 \quad 2p_x^1,\ 2p_y^1,\ 2p_z^1$

Thus, $_7N \rightarrow 1s^2, 2s^2, 2p_x^1, 2p_y^1, 2p_z^1$

(4) (n + *l*) Rule

This rule states that electrons are filled in orbitals according to their n + *l* values(n = principle quantum number & *l* = azimuthal quantum number) . When (n + *l*) is same for sub energy levels, the electrons first occupy the sublevels with lowest ‘n’ value.

Thus, order of filling up of orbitals is as follows

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

(5) Half Filled and Completely Filled Orbitals

Half-filled and completely filled sub-shells have extra stability on the basis of Exchange Energy. Extra stability is shown, when p, d, f orbitals are half filled or completely filled.

For example,

$_{24}Cr \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^4$

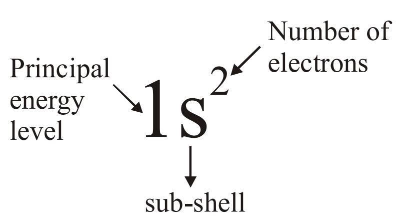
$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1, 3d^5$

$_{29}Cu \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^9$

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1, 3d^{10}$

4.16 ELECTRONIC CONFIGURATIONS OF ELECTRONS

In order to represent electron popultion of an orbital, the principal quantum number (n) is written before the orbital symbol while the number of electorn in the orbital is written superscript near the right head top of the orbital symbol. For example if we have two electrons in the s-orbital of first energy then it is written as $1s^2$.



Atomic Number	Symbol of Element	Electron Configuration	Atomic Number	Symbol of Element	Electron Configuration
1	H	$1s^1$	16	S	$[Ne]3s^2 3p^4$
2	He	$1s^2$	17	Cl	$[Ne]3s^2 3p^5$
3	Li	$[He]2s^1$	18	Ar	$[Ne]3s^2 3p^6$
4	B	$[He]2s^2$	19	K	$[Ar]4s^1$
5	Be	$[He]2s^2 2p^1$	20	Ca	$[Ar]4s^2$
6	C	$[He]2s^2 2p^2$	21	Sc	$[Ar]4s^2 3d^1$
7	N	$[He]2s^2 2p^3$	22	Ti	$[Ar]4s^2 3d^2$
8	O	$[He]2s^2 2p^4$	23	V	$[Ar]4s^2 3d^3$
9	F	$[He]2s^2 2p^5$	24	Cr	$[Ar]4s^1 3d^5$
10	Ne	$[He]2s^2 2p^6$	25	Mn	$[Ar]4s^2 3d^5$
11	Na	$[Ne]3s^1$	26	Fe	$[Ar]4s^2 3d^6$
12	Mg	$[Ne]3s^2$	27	Co	$[Ar]4s^2 3d^7$
13	Al	$[Ne]3s^2 3p^1$	28	Ni	$[Ar]4s^2 3d^8$
14	Si	$[Ne]3s^2 3p^2$	29	Cu	$[Ar]4s^1 3d^{10}$
15	P	$[Ne]3s^2 3p^3$	30	Zn	$[Ar]4s^2 3d^{10}$

4.17 SOME IMPORTANT TERMS

➢ ISOTOPES

Atoms with the same atomic number but different mass numbers are called isotopes.

(i) First proposed by **soddy**.

(ii) The isotopes have same atomic number but different atomic mass.

e.g	$_1H^1$ **(Hydrogen)**	$_1H^2$ **(Deuterium)**	$_1H^3$ **(Tritium)**
Atomic no. Z =	1	1	1
Mass no. A =	1	2	3

Other such examples

(i) Carbon $^{12}_{6}C$ and $^{14}_{6}C$ (ii) Chlorine $^{35}_{17}Cl$ and $^{37}_{17}Cl$

The chemical properties of isotopes are similar but their physical properties are different. If an element has no isotopes then the mass of its atom would be the same as sum of proton and neutrons in it. But if an element occurs in isotopic forms then the we have to know the percentage of each isotopic form and then the average mass is calculated.

The characteristics of isotopes are :

(i) They have different atomic masses (mass number).

(ii) They have the same atomic number.

(iii) They have the same electronic configuration.

(iv) They have the same valence electrons.

(v) They have the same chemical properties.

(vi) They have slightly different physical properties.

RADIOACTIVE ISOTOPES

The isotopes which are unstable (due to the presence of extra neutron in their nuclei) and emit various type of radiations are called radioactive isotopes or just radio isotopes. Some example of the radioisotopes are : Carbon-14, Iodine-131, Cobalt-60 etc. The high energy radiations emitted by radioactive isotopes are harmful to human beings.

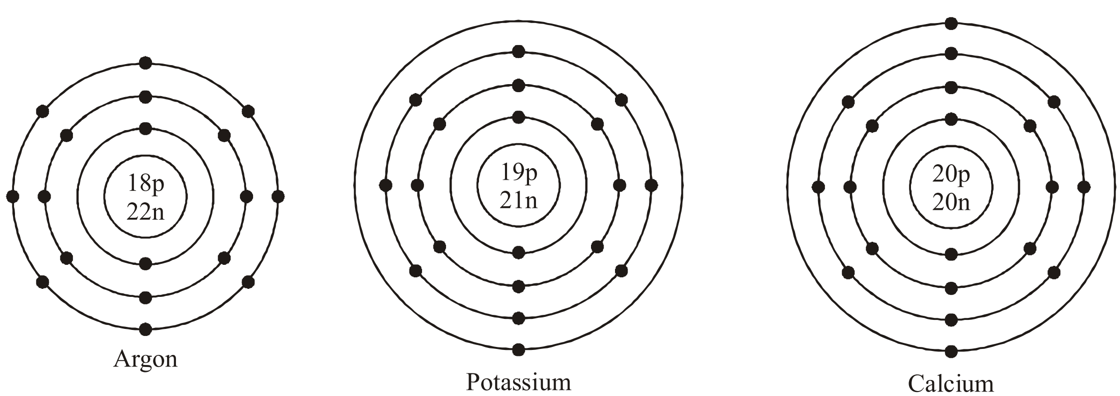
Uses of radioactive isotopes

1. **In Medicine :**
   (i) Co^{60} for treatment of cancer.
   (ii) Na^{24} for circulation of blood.
   (iii) I^{131} for thyroid.
   (iv) Sr^{90} for treatment of skin and eye.
   (v) Fe^{59} for location of brain tumor.
   (vi) Radiographs of castings and teeth.
2. **In Industries :**
   (i) For detecting leakages in water and oil pipe lines.
   (ii) For investigation of wear and tear, study of plastics and alloys, thickness measurement.
3. **In Agriculture :**
   (i) C^{14} to study kinetics of plant photosynthesis.
   (ii) P^{32} to find nature of phosphate which is best for given soil and crop.
   (iii) Co^{60} for protecting potato crop from earth worm.
   (iv) Sterilization of insects for pest control.
4. **In Scientific research :**
   (i) K^{40} to find age of meteorites.
   (ii) S^{35} in factories.
5. **As Tracers :**
   (i) A very small quantity of radio isotope present in any specimen is called tracer.
   (ii) This technique is used to study complex biochemical reactions, in detection of cracks, blockages, etc., tracing sewage or silt in sea.
6. **In Geology :**
   (i) For dating geological specimens like ancient rocks, lunar rocks using Uranium.
   (ii) For dating archaeological specimens, biological specimens using C^{14}.

➢ ISOBAR

The two different atoms which have same atomic masses but different atomic number is called as isobar

e.g.	$_{18}Ar^{40}$	$_{19}K^{40}$	$_{20}Ca^{40}$
Atomic mass	40	40	40
Atomic number	18	19	20



The characteristics of isobars are :

(i) They have the same mass number.
(ii) They have different atomic numbers.
(iii) They have different number of protons.
(iv) They have different electronic configurations.
(v) They have different number of valence electrons.
(vi) They have different chemical properties.

➢ ISOELECTRONIC

Ion or atom or molecule or species which have the same number of electron is called isoelectronic species.

e.g. Na^+, Mg^{+2}, F^-, O^{-2}, Al^{+3} are isoelectronic.

➢ ISOSTERS

Substance which have same number of electron and atoms called Isosters.

e.g.	CO_2	N_2O
	22	22

➢ ISODIAPHERES

The elements which have same value of (n–p) is called isodiapheres.

e.g.	$_7N^{14}$	$_8O^{16}$
value of (n – p)	0	0

➢ ISOTONES

Elements which contain same number of neutron is called isotones.

e.g.	$_{14}Si^{30}$	$_{15}P^{31}$	$_{16}S^{32}$
number of neutrons	16	16	16

➢ KERNEL & CORE

Orbit which present after removing the outer most orbit of that atom is called kernel and electrons which is present that orbit called kernel electrons e.g. Mg = $1s^2 2s^2 2p^6 3s^2$.

Total kernel electron = 2 + 2 + 6 = 10

(i) The outer most shell of an any atom called Core and the number of electron present of that shell is called Core electron. e.g. Cl = $1s^2 2s^2 2p^6 3s^2 3p^5$
Core electron = 2 + 5 = 7

(ii) If the core is unstable for an atom then that atom shows variable valency.

Knowledge Enhancer

Exceptional Configuration - Stability of Completely Filled and Exactly Half-filled Orbitals :

However in certain element when the two subshells differ slightly in their energies, an electron may shift from a subshell of lower energy to a subshell of higher energy only if such a shift results in the symmetrical distribution (either completely filled or exactly half-filled) of the electrons in the various orbitals of the shell of higher energy. This is due to the following two reasons :

(i) **Symmetrical distribution :** It is well known fact that symmetry leads to stability. Thus the electronic configuration in which all the orbitals of the same subshell are either completely filled or are exactly half filled are more stable because of symmetrical distribution of electrons. For example, the expected electronic configuration of chromium (Z = 24) is

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$

But if one of the 4s-electrons shifts to the vacant 3d-orbital, the distribution of the electrons will become more symmetrical and this will impart extra stability.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

(ii) **Exchange energy :** The electrons with parallel spins present in the degenerate orbitals tend to exchange their position. The energy released during this exchange is called exchange energy. The number of exchange that can take place is maximum when the degenerate orbitals are exactly half-filled or completely filled. As a result, the exchange energy is maximum and so is the stability.

POINTS TO REMEMBER

- **Atom** is smallest particle consisting of three fundamental particles namely electron, proton and neutron.
- **Electron :** Discovered by J.J. Thomson, negatively charged particle carrying 1.60×10^{-19} C and has mass of 1.60211×10^{-31} kg.
- **Proton** is a positively charged particle and has mass equal to 1.672614×10^{-27} kg.
- Proton was discovered by **Goldstein** and neutron by **Chadwick**.
- **Neutron** is a neutral particle and has mass equal to 1.67492×10^{-27} kg.
- **Rutherford**'s model of atom was modified by Bohr in 1913.
- He postulated that so long as the electron is in a particular orbit it neither absorbs nor emit energy. In other words no energy is required for the movement of the electrons in these orbits on the other hand a definite amount of energy is absorbed or emitted when the electron moves from one orbit to the other.
- **Limitation of Bohr's Model :**
  - (i) Bohr's model could explain the line spectra of H atom and hydrogen line species but failed to explain the spectra of multi electron atom .
  - (ii) It could not explain the splitting of spectral lines into finer lines under the influence of magnetic effect (**Zeeman effect**) and electric effect (**Stark effect**)
  - (iii) This is not in accordance with de Broglie concept of dual nature of matter and Heisenberg Uncertainty Principle.
- **Atomic number** is the number of protons present in the nucleus of an atom whereas **Mass number** is the sum total of protons and neutrons. (may called nucleons)
- **Isotopes** are different atoms of the same element having same atomic number but different mass number.

  e.g. [${}^{1}_{1}H$; ${}^{2}_{1}D$; ${}^{3}_{1}T$ and ${}^{35}_{17}Cl$; ${}^{37}_{15}Cl$]
- **Isobars** are Atoms of different elements having same mass number but different atomic number.

  [${}^{40}_{18}Ar$; ${}^{40}_{19}K$; ${}^{40}_{20}Ca$]
- **Quantum numbers** is set of four numbers used to locate the electron and to determine the amount of energy associated with it. Out of four, three quantum numbers are derived from Schrodinger equation and are associated with the orbit and fourth is associated with electron.
- Principal quantum number explains the main lines in the spectrum and represents the main shell, **azimuthal quantum number** explains five lines in the spectrum and represents the number of sub shells present in the main shell, and magnetic quantum number explains splitting of lines under the influence of magnetic field and represents the number of orbital present in any subshell.

- **Spin Quantum Number** is associated with the electron and describes the spin of the electron which can be either clockwise or anti-clockwise hence have the values $+\frac{1}{2}$ (denoted by the arrow $\uparrow$) and $-\frac{1}{2}$ (denoted by the arrow $\downarrow$).
- **Maximum number of electrons in**

  (i) s-sub shell can be 2; (ii) p-sub shell can be 6

  (iii) d- sub shell can be 10; (iv) f-sub- shell can be 14
- Filling of orbital's by electrons take place according to **Aufbau Rule**; **Pauli's exclusion Principle** and **Hund's rule** maximum multiplicity.
- To write the electronic configuration of a cation, first write the electronic configuration of atom and then remove number of electrons equal to the units of positive charges starting from the outermost shell.
- **Aufbau Principle**
  - "An electron enters the orbital's that has least energy" i.e. electron enters the orbital for which $n + l$ is minimum, however, if $n + l$ is same for two configuration then election will enter the orbital with lower value of n.
  - The sequence of filling the orbital's is 1s, 2s, 2p, 3s, 3p, 4s, 3d , 4p, 5s, 4d, 5p , 6s, 4f, 5d, 6p, 7s and so on.
- **Hund's Rules of Maximum multiplicity or minimum pairing**
  - "No pairing of electrons in a degenerate orbital can take place until each degenerate orbital is singly filled".
  - This is because the electron should be maximum distance apart so as to have minimum repulsion and secondary electron entering different orbits should have paralled spin so that maximum possible exchanges can take place.
- **Pauli's Exclusion Principle :** According to Pauli's Exclusion Principle, "**no two electrons in an atom can have all the four quantum number same**" i.e. if two electrons occupy the same orbital they must have opposite spin hence it restricts the number of electrons to two in an orbital.
- Space in which there is maximum probability of finding the electron is known as orbital.
- **Isotones** are Atoms of different elements having same number of neutrons e.g .[$^{14}_{6}C$; $^{15}_{7}N$; $^{16}_{8}O$]

CONCEPT APPLICATION LEVEL - I [NCERT Questions]

Q.1 What are canal rays?

Ans. Canal rays are positively charged radiations. These rays consist of positively charged particles. They were discovered by Goldstein in 1886.

Q.2 If an atom contains one electron and one proton, will it carry any charge or not?

Ans. An electron is a negatively charged particle, where as a proton is a positively charged particle. The magnitude of their charges is equal. Therefore, an atom containing one electron and one proton will not carry any charge. Thus, it will be a neutral atom.

Q.3 On the basis of Thomson's model of an atom, explain how the atom is neutral as a whole.

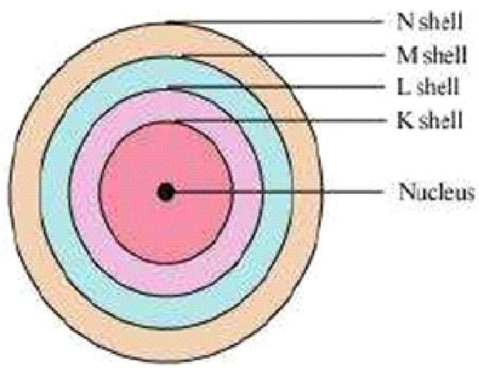
Ans. According to Thomson's model of the atom, an atom consists of both negatively and positively charged particles. The negatively charged particles are embedded in the positively charged sphere. These negative and positive charges are equal in magnitude. Thus, by counter balancing each other's effect, they make an atom neutral.

Q.4 On the basis of Rutherford's model of an atom, which subatomic particle is present in the nucleus of an atom?

Ans. On the basis of Rutherford's model of an atom, protons (positively charged particles) are present in the nucleus of an atom.

Q.5 Draw a sketch of Bohr's model of an atom with three shells.

Ans. Bohr's model of an atom with three shells.



Q.6 What do you think would be the observation if the α-particles scattering experiment is carried out using a foil of a metal other than gold?

Ans. If the α-scattering experiment is carried out using a foil of a metal rather than gold, there would be no change in the observation. In the α-scattering experiment, a gold foil was taken because gold is malleable and a thin foil of gold can be easily made. It is difficult to make such foils from other metals.

Q.7 Name the three sub atomic particles of an atom.

Ans. The three sub atomic particles of an atom are:

(i) Protons (ii) Electrons, and (iii) Neutrons

Q.8 Helium atom has an atomic mass of 4u and two protons in its nucleus. How many neutrons does it have?

Ans. Helium atom has two neutrons. The mass of an atom is the sum of the masses of protons and neutrons present in its nucleus. Since helium atom has two protons, mass contributed by the two protons is (2×1)u = 2u.Then, the remaining mass $(4 - 2)$u = 2u is contributed by neutrons.

Q.9 Write the distribution of electrons in carbon and sodium atoms?

Ans. The total number of electrons in a carbon atom is 6. The distribution of electrons in carbon atom is given by:

First orbit or K-shell = 2 electrons
Second orbit or L-shell = 4 electrons

or, we can write the distribution of electrons in a carbon atom as 2, 4.

The total number of electrons in a sodium atom is 11. The distribution of electrons in sodium atom is given by:

First orbit or K-shell = 2 electrons
Second orbit or L-shell = 8 electrons
Third orbit or M-shell = 1 electron

or, we can write distribution of electrons in a sodium atom as 2, 8, 1.

Q.10 If K and L shells of an atom are full, then what would be the total number of electrons in the atom?

Ans. The maximum number of electrons that can occupy K and L-shells of an atom are 2 and 8 respectively. Therefore, if K and L-shells of an atom are full, then the total number of electrons in the atom would be $(2 + 8) = 10$ electrons.

Q.11 How will you find the valency of chlorine, sulphur and magnesium?

Ans. If the number of electrons in the outer most shell of the atom of an element is less than or equal to 4, then the valency of the element is equal to the number of electrons in the outer most shell. On the other hand, if the number of electrons in the outer most shell of the atom of an element is greater than 4, then the valency of that element is determined by subtracting the number of electrons in the outer most shell from 8. The distribution of electrons in chlorine, sulphur, and magnesium atoms are 2, 8, 7; 2, 8, 6 and 2, 8, 2 respectively. Therefore, the number of electrons in the outer most shell of chlorine, sulphur, and magnesium atoms are 7, 6 and 2 respectively.

Thus, The valency of chlorine = $8 - 7 = 1$
The valency of sulphur = $8 - 6 = 2$
The valency of magnesium = 2

Q.12 If number of electrons in an atom is 8 and number of protons is also 8, then (i) what is the atomic number of the atom and (ii)what is the charge on the atom?

Ans. (i) The atomic number is equal to the number of protons. Therefore, the atomic number of the atom is 8.
(ii) Since the number of both electrons and protons is equal, therefore, the charge on the atom is 0.

Q.13 With the help of Table find out the mass number of oxygen and sulphur atom.

Name of element	Symbol	Atomic Number	Number of protons	Number of neutrons	Number of electrons
Oxygen	O	8	8	8	8
Sulphur	S	16	16	16	16

Ans. Mass number of oxygen = Number of protons + Number of neutrons = 8 + 8 =16
Mass number of sulphur = Number of protons + Number of neutrons = 16 + 16 = 32.

Q.14 For the symbol H, D and T tabulate three sub-atomic particles found in each of them.

Ans.

Symbol	Proton	Neutron	Electron
H	1	0	1
D	1	1	1
T	1	2	1

Q.15 Write the electronic configuration of any one pair of isotopes and isobars.

Ans. Two isotopes of carbon are C_6^{12}, C_6^{13}. [Isotopes have the same electronic configuration]

and The electronic configuration of C_6^{12} is 2, 4.

The electronic configuration of C_6^{13} is 2, 4.

and Ca_{20}^{40}, Ar_{19}^{40} are a pair of isobars

The electronic configuration of Ca_{20}^{40} is 2, 8, 8, 2.

The electronic configuration of Ar_{18}^{40} is 2, 8, 8.

Q.16 Compare the properties of electrons, protons and neutrons.

Ans. Electron

(i) Electrons are present outside the nucleus of an atom.

(ii) Electrons are negatively charged.

(iii) The mass of an electron is considered to negligible.

Proton

(i) Protons are present in the nucleus of an atom.

(ii) Protons are positively charged.

(iii) The mass of a proton is approximately 2000 times as the mass of an electron.

Neutron

(i) Neutrons are present in the nucleus of an atom.

(ii) Neutrons are neutral

(iii) The mass of neutron is nearly equal to the mass of a proton.

Q.17 What are the limitations of J. J. Thomson's model of the atom?

Ans. (i) According to J. J. Thomson's model of an atom, an atom consists of a positively charged sphere with electrons embedded in it. However, it was later found that the positively charged particles reside at the centre of the atom called the nucleus, and the electrons revolve around the nucleus.

(ii) J.J. Thomson’s model of the atom was just based on imagination, it did not have any experimental evidence in it’s support.

Q.18 What are the limitations of Rutherford's model of the atom?

Ans. According to Rutherford's model of an atom, electrons revolve around the nucleus in fixed orbits. But, an electron revolving in circular orbits will not be stable because during revolution, it will experience acceleration. Due to acceleration, the electrons will lose energy in the form of radiation and fall into the nucleus. In such a case, the atom would be highly unstable and collapse.

Q.19 Describe Bohr's model of the atom.

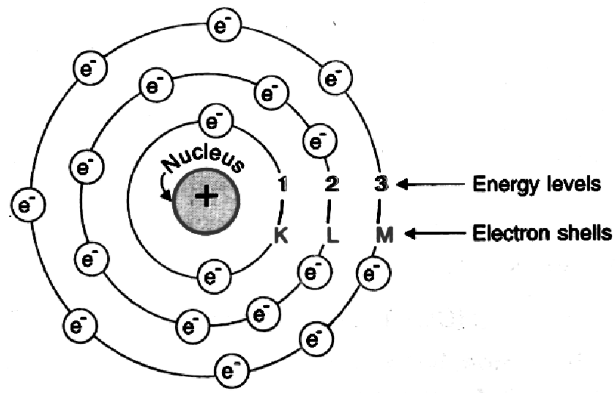
Ans. Bohr's model of the atom

Niels Bohr proposed the following postulates regarding the model of the atom.

(i) Only certain orbits known as discrete orbits of electrons are allowed inside the atom.

(ii) While revolving in these discrete orbits, the electrons do not radiate energy.

These discrete orbits or shells are shown in the following diagram.



The first orbit (i.e., for n =1) is represented by letter K. Similarly, for n = 2, it is L-shell, for n = 3, it is M-shell and for n = 4, it is N-shell. These orbits or shells are also called energy levels.

Q.20 Compare the properties of electrons, protons and neutrons.

Ans:

Particle	Nature of charge	Mass	Location
Electron	Negative	(–1) or $(-1.6 \times 10^{-19}$ C) or 9×10^{-31} kg	Outside the nucleus (Extra nuclear part distributed in different shells or orbits.)
Proton	Positive	(+1) or $(+1.6 \times 10^{-19}$ C) or 1.672×10^{-27} kg (1 u) (approx. 2000 times that of the electron)	In the nucleus
Neutron	No charge	1.672×10^{-27} kg (1 u) (mass is nearly equal; to the mass of a proton)	In the Nucleus

Q.21 Compare all the proposed models of an atom given in this chapter.

Ans: Thomson's Model :

1. An atom consists of a positively charged sphere and the electrons are embedded in it.
2. The negative and positive charges are equal in magnitude. As a result the atom is electrically neutral.

Rutherford's Model :

1. An atom consists of a positively charged center in the atom called the nucleus. The mass of the atom is contributed mainly by the nucleus.
2. The size of the nucleus is very small as compared to the size of the atom.
3. The electrons revolve around the nucleus in well-defined orbits.

Bohr's Model :

1. Bohr agreed with almost all points as said by Rutherford except regarding the revolution of electrons for which he added that there are only certain orbits known as discrete orbits inside the atom in which electrons revolve around the nucleus.
2. While revolving in its discrete orbits the electrons do not radiate energy.

Q.22 Summarise the rules for writing of distribution of electrons in various shells for the first eighteen elements.

Ans. Following rules are followed to fill electrons in different energy levels.

1. If n gives the number of orbit or energy level, then $2n^2$ gives the maximum number of electrons possible in a given orbit or energy level. Thus,
   Ist orbit or K-shell will have 2 electrons,
   IInd orbit or L-shell will have 8 electrons,
   IIIrd orbit or M-shell will have 18 electrons.
2. If it is the outermost orbit, then it should have not more than 8 electrons.
3. There should be step-wise filling of electrons in different orbits, i.e., electrons are not accompanied in a given orbit if the earlier orbits or shells are incompletely filled.

Q.23 Define valency by taking examples of silicon and oxygen.

Ans. The valency of an element is the combining capacity of that element. The valency of an element is determined by the number of valence electrons present in the atom of that element.

If the number of valence electrons of the atom of an element is less than or equal to four, then the valency of that element is equal to the number of valence electrons.

For example, the atom of silicon has four valence electrons and so, it has valency equal to four.

On the other hand, if the number of valence electrons of the atom of an element is greater than 4, then the valency of that element is obtained by subtracting the number of valence electrons from 8. For example, the atom of oxygen has 6 valence electrons and so, the valency of oxygen is (8 – 6) =2.

Q.24 Explain with examples (i) Atomic number, (ii) Mass number, (iii) Isotopes and (iv) Isobars. Give any two uses of isotopes.

Ans: Atomic Number is defined as the number of protons present in the nucleus of an atom. For example, there are 6 protons in carbon, so the atomic number of carbon is 6. All atoms are characterized by their atomic numbers.

Mass Number is defined as the sum of the total number of protons and neutrons present in the nucleus of an atom. For example, there are 6 protons and 6 neutrons in the nucleus of carbon, so its mass number is 12.

Isotopes are atoms of the same element thus having same atomic number but different mass number. For example, chlorine has two isotopes with atomic number 17 but mass numbers 35 and 37 represented by

Two Uses of Isotopes :

(a) Isotope of cobalt (^{60}Co) is used in the treatment of cancer.

(b) Isotope of uranium (^{235}U) is used as a fuel in nuclear reactors.

Isobars are such atoms which have same mass number but different atomic numbers. Thus, isobars are different elements. For example, Ne has atomic number 10 and sodium has atomic number 11 but both of them have mass numbers as 22 represented by, Ne_{10}^{22}, Na_{11}^{22}.

Q.25 Na^+ has completely filled K and L shells. Explain.

Ans. The atomic number of sodium is 11. So, neutral sodium atom has 11 electrons and its electronic configuration is 2, 8, 1. But Na^+ has 10 electrons. Out of 10, K-shell contains 2 and L-shell 8 electrons respectively. Thus, Na^+ has completely filled K and L shells.

$$Na \longrightarrow Na^+ + 1e^-$$

Q.26 If bromine atom is available in the form of, say, two isotopes $^{79}_{35}Br(49.7\%)$ and $^{81}_{35}Br(50.3\%)$, calculate the average atomic mass of bromine atom.

Ans. We known that $^{79}_{35}Br$, $^{81}_{35}Br$ are isotope of bromine with atomic mass 79 u = 49.7% and 81 u = 50.3%.

Average atomic mass of element $= u_1 \times \% + u_2 \times \%$

$$= 79 \times \frac{49.7}{100} + 81 \times \frac{50.3}{100}$$

$$= 39.26 + 40.74 = 80 \text{ u}$$

$\therefore$ Average atomic mass of Br = 80 u.

Q.27 The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes $^{16}_{8}X$ and $^{18}_{8}X$ in the sample?

Ans: Atomic mass of element X = 16.2 u

Let the percentage of isotope $^{16}_{8}X$ be x.

Percentage of the isotope $^{18}_{8}X = (100 - x)$

$$\text{Atomic mass of 'X'} = \frac{\% \text{ of } ^{16}_{8}X \times 16u + \% \text{ of } ^{18}_{8}X \times 18u}{100}$$

$$16.2 \text{ u} = \frac{x \times 16u + (100 - x) \times 18u}{100}$$

$$1620 \text{ u} = 16x + 1800 - 18x$$

$$2x = 180$$

$$x = \frac{180}{2} = 90\%$$

$\therefore$ % of Isotope $^{16}_{8}X = 90\%$

$\therefore$ % of Isotope $^{18}_{8}X = 10\%$

Q.28 If Z = 3, what would be the valency of the element? Also name the element.

Ans. If Z = 3, i.e., atomic number is 3. The element is lithium and has distribution of electrons as 2, 1. And so, lithium has a valency of 1.

Q.29 Composition of the nuclei of two atomic species X and Y are given as under

	X	Y
Protons =	**6**	**6**
Neutrons =	**6**	**8**

Give the mass numbers of X and Y. What is the relation between the two species?

Ans: Mass number of X = 6 + 6 = 12
Mass number of Y = 6 + 8 = 14
Since X and Y both have atomic numbers as 6 but mass numbers are different, therefore, these are isotopes.

Q.30 For the following statements, write T for True and F for False.
(a) J.J. Thomson proposed that the nucleus of an atom contains only nucleons.
(b) A neutron is formed by an electron and a proton combining together. Therefore, it is neutral.
(c) The mass of an electron is about 1/2000 times that of proton.
(d) An isotope of iodine is used for making tincture iodine, which is used as a medicine.

Ans: (a) False (b) False (c) True (d) True

Put tick (✓) against correct choice and cross (✗) against wrong choice in the following questions:

Q.31 Rutherford's alpha-particle scattering experiment was responsible for the discovery of
(A) Atomic Nucleus (B) Electron (C) Proton (D) Neutron. Ans: (A)

Q.32 Isotopes of an element have
(A) the same physical properties (B) different chemical properties
(C) different number of neutrons (D) different atomic numbers. Ans: (C)

Q.33 Number of valence electrons in Cl^- ion is:
(A) 16 (B) 8 (C) 17 (D) 18 Ans: (B)

Q.34 Which one of the following is a correct electronic configuration of sodium?
(A) 2, 8 (B) 8, 2, 1 (C) 2, 1, 8 (D) 2, 8, 1 Ans: (D)

Q.35 Complete the following table.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	–	10	–	–	–
16	32	–	–	–	Sulphur
–	24	–	12	–	–
–	2	–	1	–	–
–	1	0	1	0	–

Ans:

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	19	10	9	9	Fluorine
16	32	16	16	16	Sulphur
12	24	12	12	12	Magnesium
1	2	1	1	1	Deuterium
1	1	0	1	0	Protium

CONCEPT APPLICATION LEVEL - II

SECTION-A

- **Multiple Choice question with one correct answers**

Q.1 An atom with atomic number 18 and mass number 40, has the following arrangement.
(A) 18p, 18e, 22n (B) 18p, 18e, 40n (C) 22p,18e, 18n (D) 22p, 22e,18n

Q.2 Which of the following pairs of species are iso-electronic ?
(A) H_2O, H_2S (B) NO_3^-, CO_3^{2-} (C) H_3O^+, K^+ (D) HF, HCl

Q.3 Which of the following statements is correct ?
(A) ${}_7N^{14}$ and ${}_6C^{13}$ are isotones (B) ${}_7N^{14}$ and ${}_6C^{14}$ are isotopes
(C) ${}_7N^{14}$ and ${}_6C^{12}$ are isobars (D) ${}_7N^{14}$ and ${}_6C^{15}$ are isotones

Q.4 When atoms of the gold sheet are bombarded by a beam of α-particles, only a few α-particles get deflected whereas most of them go straight undeflected. This is because:
(A) the force of attraction on α-particles by the oppositely charged electron is not sufficient.
(B) the nucleus occupies much smaller volume as compared to the volume of atom
(C) the force of repulsion on fast moving α-particles is very small.
(D) the neutrons in the nucleus do not have any effect on α-particles

Q.5 The possible sub shells in n = 3 energy shell are
(A) s, p, d (B) s, p, d, f (C) s, p (D) s only

Q.6 Indicate which electronic configuration amongst the following correctly represent SULPHUR atom ?
(A) $1s^2 2s^2 2p^6 3s^2 3p^2 3d^2$ (B) $1s^2 2s^2 2p^6 3s^2 3p^2 4s^2$
(C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 4p^1$ (D) $1s^2 2s^2 2p^6 3s^2 3p^4$

Q.7 The number of d-electrons in Fe^{2+} (atomic number = 26) is equal to that of
(A) p-electrons in ${}_{10}Ne$ (B) s-electrons in ${}_{12}Mg$
(C) d-electrons in Fe (D) p-electrons in Cl

Q.8 Rutherford's alpha particle scattering experiment led to the discovery of
(A) Nucleus (B) Electrons (C) Protons (D) Neutrons

Q.9 The radioactive isotope used in the treatment of cancer is
(A) Plutonium-239 (B) Arsenic-74 (C) Cobalt-60 (D) Iodine-131

Q.10 These are four elements P, Q, R and S having atomic numbers of 4, 18, 10 and 16 respectively. The element which can exhibit covalency as well as electrovalency will be
(A) P (B) Q (C) R (D) S

SECTION-B

- **VERY SHORT ANSWER TYPE QUESTIONS (One Mark Questions)**

Q.1 In the notation of nitrogen $^{14}_{7}N$, what do the number 14 and 7 denote?

Ans. The number 14 represents mass number and 7 represents atomic number.

Q.2 What is the difference between Na and Na^{+} in terms of number of electrons?

Ans. Na atom has 11 electrons, whereas Na^{+} ion has 10 electrons

Q.3 Which sub-atomic particles of an atom are responsible for atomic mass?

Ans. Neutrons and protons are responsible for atomic mass.

Q.4 Identify the pair of isotopes from the following :

$^{16}_{8}X$, $^{16}_{7}X$, $^{17}_{8}X$

Ans. $^{16}_{8}X$ and $^{17}_{8}X$ are isotopes.

Q.5 An atom of an element is represented as $^{19}_{9}X$. How many electrons and neutrons are present in this atom?

Ans. Electrons = 9, Neutrons = 10

Q.6 Write the mass number of neon and argon from the data given below :

Electron	No. of protons	No. of neutrons
Neon	10	10
Argon	18	22

Ans. Mass number of Neon = p + n = 10 + 10 = 20

Mass number of Argon = p + n = 18 + 22 = 40

Q.7 What are the maximum number of electrons that can be accommodated in outermost shell of an atom?

Ans. The maximum number of electrons which can be present in outermost shell is 8.

Q.8 Who discovered the neutron?

Ans. Chadwick discovered neutron.

Q.9 What happens to an element 'Z' if its atom gains three electrons?

Ans. It acquires three negative charge, i.e. Z^{3-} ion is formed.

Q.10 Name the three sub-atomic particle of an atom.

Ans. Electron, Proton and Neutron

- **SHORT ANSWER TYPE QUESTIONS (Two Marks Questions)**

Q.1 The following data represents the distribution of electrons, protons and neutrons in atoms of four elements A, B, C, D.

Elements	Protons	Neutrons	Electrons
A	19	21	19
B	17	18	17
C	17	20	17
D	18	22	18

Answer the following questions :

(a) Describe the electronic distribution in atom of element B.

(b) Is element B a metal or a non-metal? Why?

(c) Which two elements form a pair of Isotopes?

(d) Which two elements form a pair of Isobars?

Ans. (a) B(17) K L M

2 8 7

(b) B is a non-metal because it can gain one electron to become stable and forms negative ion.

(c) 'B' and 'C' are isotopes as they differ in number of neutrons.

(d) 'A' and 'D' are isobars as both of them have same mass number 40 but different atomic numbers (19 and 18).

Q.2 (a) Why is Thomson's model of an atom compared with watermelon?

(b) Why do isotopes have different mass number?

Ans. (a) Thomson proposed that atom consists of positively charged sphere in which electrons are embedded like seeds in watermelon.

(b) They differ in number of neutrons, therefore, they have different mass numbers.

Q.3 Given reason for the following :

(a) Nucleus of an atom is heavy and positively charged.

(b) An atom is electrically neutral.

Ans. (a) Nucleus is positively charged due to presence of protons. It is heavy because whole mass of atom is concentrated in nucleus due to protons and neutrons.

(b) An atom is electrically neutral due to the presence of equal number of electrons (negatively charged) and protons (positively charged)

Q.4 Name the constituent of an atom. What is the net charge on the nucleus of an atom?

Ans. Atom consists of electrons, protons and neutrons.

Nucleus of an atom is positively charged.

Q.5 Mention any two points Rutherford put forward to explain the nuclear model of an atom.

Ans. (a) Most of the part of atom is hollow.

(b) Atom consists of positively charged centre called nucleus where whole mass of atom is concentrated.

Q.6 State the characteristics of nucleus of an atom.

Ans. (a) It is heavy.

(b) It is positively charged.

(c) Its density is very high.

(d) Its size is $\frac{1}{100,000}$ of the size of atom.

Q.7 Is it possible for the atom of an element to have one electron, one proton and no neutron. If so, name the element.

Ans. Yes, the element is hydrogen.

Q.8 Write any two observations which support that fact that atoms are divisible.

Ans. (a) Discovery of electrons

(b) Discovery of neutrons

Q.9 In response to a question, a student stated that in an atom, the number of protons is greater than the number of neutrons, which in turn is greater than the number of electrons. Do you agree with the statement? Justify your answer.

Ans. No, its is not possible. Number of protons can not be greater than number of electron in case of neutral atoms. These should be equal. Number of protons also can not be greater then neutron except in case of hydrogen.

Q.10 What is the reason for the identical chemical properties of all the isotopes of an element?

Ans. Isotopes of an element has identical chemical properties because their electronic configuration is same. They have ;same number of valence electron.

- **SHORT ANSWER TYPE QUESTIONS (Three Marks Questions)**

Q.1 Which of the following are isotopes and which are isobars?

Argon, Protium, Calcium, Deuterium.

Explain, why the isotopes have similar chemical properties but they have differ in physical properties?

Ans. ${}^{1}_{1}H$ (Protium) and ${}^{2}_{1}H$ (Deuterium) are isotopes ${}^{40}_{18}Ar$ and ${}^{40}_{20}Ca$ are isobars.

Isotopes have similarity in chemical properties as these have same atomic number i..e same number of valence electrons but differ in physical properties due to difference in mass number.

Q.2 (a) Explain Bohr and Bury rules for distribution of electrons into different shells.

(b) Draw the electronic structure of element X with atomic number 17 and element Y with atomic number 16?

Ans. (a) **Bohr and Bury Scheme for Distribution of Electrons in Different Energy Levels :**

(i) The maximum number of electrons in an energy level is equal to $2n^2$ where 'n' is the energy level.

1^{st} energy level can have $2n^2 = 2 \times 1^2 = 2$ electrons

2^{nd} energy level can have $2 \times 2^2 = 8$ electrons

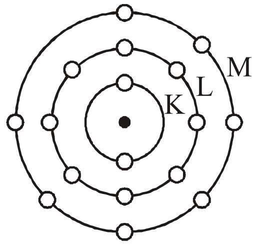
3^{rd} energy level can have $2 \times 3^2 = 18$ electrons

(ii) The last energy level (outermost energy level) cannot have more than 8 electrons.

(iii) The last but one shell (penultimate shell) cannot have more than 18 electrons.

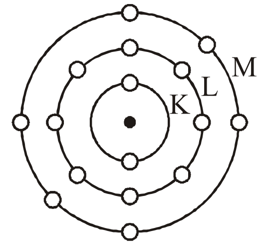
(iv) The last but second shell (anti-penultimate shell) cannot have more than 32 electrons.

(b) X(17) = 2, 8, 7



K = 2, L = 8, M = 7

Y(16) = 2, 8, 6



K = 2, L = 8, M = 6

Q.3 State the observations in α-particle scattering experiment which led Rutherford to make the following conclusions :

(a) Most of the space in an atom is empty.
(b) Whole mass of an atom is concentrated in its centre.
(c) Centre is positively charged.

Ans. (a) Most of the rays passed through thin gold foil undeviated.
(b) Very few rays came back in the same path.
(c) Some rays deflected through larger angles.

Q.4 Two elements X and Y combine in a ratio of 3 : 8 by mass and the compound 'Z' is formed. Z is one of the essential components of photosynthesis to take place. If Z is also one of the green house gases:

(a) Identify X, Y and Z
(b) Write the electronic configuration of X and Y.
(c) Write the atomicity of the molecule Z.

Ans. (a) 'X' and 'Y' are carbon and oxygen. These combine in ratio of 12 : 32 i.e., 3 : 8. 'Z' is carbon dioxide.
(b) 'X' has electronic configuration 2, 4.
'Y' has electronic configuration 2, 6.
(c) 'Z' is triatomic molecule.

Q.5 Elements from A to F have in them the distribution of electrons, neutrons and protons as follows :

Atoms/ions	Number of Electrons	Number of Neutrons	Number of Protons
A	4	4	3
B	10	12	11
C	17	18	17
D	17	20	17
E	18	22	18
F	19	21	19

Making use of these data, find

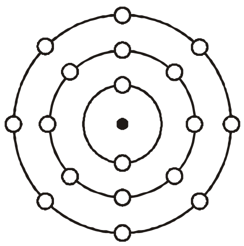
(a) a pair of ions
(b) an atom of a noble gas
(c) a pair of isobars
(d) a pair of isotopes

Ans. (a) A and B are ions (b) E is noble gas (c) E and F are isobars (d) C & D are isotopes

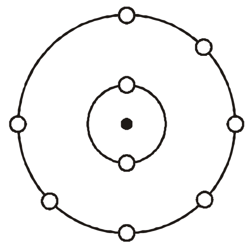
Q.6 Why metals are electropositive and non-metals are electronegative in nature.

Ans. Metal are electro positive in nature because all metals loose electron from their outermost shell in order to become stable and hence become positively charged. Non-metals are electronegative in nature because all non-metals gain electrons in order to become stable and hence become negatively charged.

Q.7 Find out the valency of the atoms represented by the figure (a) and (b). What is special about electronic configuration of element represental by figure (a).



(a)



(b)

Ans. (a) has valency equal to zero as its octate is complete, i.e. it has 8 electrons in its valence shell.

(b) has valency equal to 1 as it has 7 valence electrons. It can gain or share 1 electron to become stable.

Element represent by figure (a) have stable full-filled inert gas or nobel gas electronic configuration.

Q.8 What is a proton? How does it differ from a neutron?

Ans. Proton is a subatomic particle. It is denoted by symbol 'P'. It has mass slightly less then neutron (1.6726×10^{-27} kg) and has unit positive charge ($+1.6022 \times 10^{-19}$ C). It is located in nucleus of atom like neutron.

It carry unit positive charge whereas neutron is neutral or chargeless78.

Q.9 What do you understand by the term "electronic configuration" of an element. Write down electronic configuration of oxygen (Atomic number 8)

Ans. Electronic configuration is the distribution of electrons in an atom. The arrangement of electrons in the various shell (or energy levels) of an atom of the element is known as electronic configuration.

Electronic configuration of oxygen.

K	L
2	6

Q.10 What are isobars? Explain why isotopes of an elements have slight difference in their physical properties.

Ans. Isobars are the atoms of different elements having different atomic number but the same mass number (or same atomic mass).

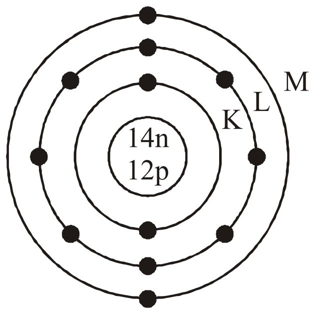
Since the masses of the isotopes of an element are slightly different therefore, the physical properties of the isotopes of an element are slightly different.

- **LONG ANSWER TYPE QUESTIONS (Five Marks Questions)**

Q.1 (a) An element has an atomic number 12 and an atomic mass no. 26. Draw a diagram showing the distribution of electrons in the orbits and the nuclear composition of the neutral atom of the element. What is the valency of the element and why?

(b) If this element X combines with another element Y whose electronic configuration is 2, 8, 7, what will be the formula of the compound thus formed? State how did you arrive at this formula.

Ans. (a)

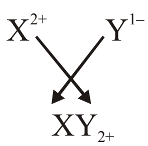


K = 2, L = 8, M = 2

$$p + n = 26$$
$$12 + n = 26$$
$$n = 26 - 12 = 14$$

Its valency is equal to 2 as it can lose 2 electrons to become stable. Its nucleus has 12 protons and 14 neutrons.

(b) Formula of the compound XY_2. It is bivalent.
Y has electronic configuration 2, 8, 7. Therefore, valency = 1. i.e. it is monovalent

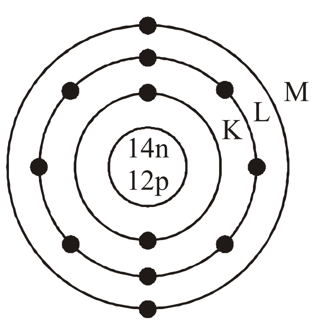


Q.2 (a) What is an octet? How do elements reach an octet?

(b) Make a schematic atomic structure of magnesium or Phosphorus.
(Given : Number of protons of Magnesium = 12, Phosphorus = 15)

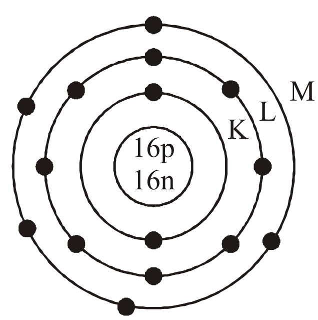
Ans. (a) When an atom has 8 electron in outermost shell, it has octet. An element can attain octet by losing, gaining or sharing electrons.

(b) Magnesium Phosphorus



K = 2, L = 8, M = 2

or



K = 2, L = 8, M = 5

Q.3 How were cathode rays produced using a discharge tube? Give four properties of cathode rays. Why does e/m ratio of negatively charged particles remains constant for all gases? Draw a neat and labelled diagram of a cathode ray tube.

Ans. When high voltage of 10000 V is passed through discharge tube at very low pressure, cathode rays are produced.

Properties of cathode rays :

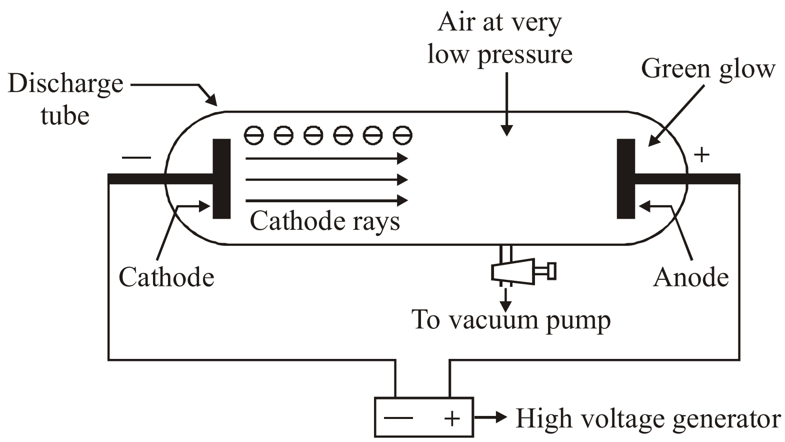
(a) They consist of negatively charged particles.

(b) The e/m ratio of particles of cathode rays is found to be same.

(c) Cathode rays are deviated towards +ve terminal in electric field.

(d) The deviation towards +ve terminal is more in electric field.

It is because electrons are present in all the atoms i.e. they are fundamental particles of all atoms. Therefore, e/m ratio of negatively charged particles remains constant.



Production of cathode rays

Q.4 The ratio of the radii of hydrogen atom and its nucleus is $10^5 : 1$. Assuming the atom and the nucleus to be spherical,

(a) What will be the ratio of their sizes?

(b) If atom is represented by planet earth 'R_e' = 6.4×10^6 m, estimate the size of the nucleus.

Ans. (a) Volume of sphere $= \frac{4}{3}\pi r^3$

Volume of atom $= \frac{4}{3}\pi R^3$ [where 'R' is radius of atom]

Volume of nucleus $= \frac{4}{3}\pi r^3$ [where 'r' is radius of nucleus]

Radius of atom (R) = $10^5 \times$ radius of nucleus (r)

$\therefore$ Volume of atom $= \frac{4}{3}\pi(10^5 r)^3 = \frac{4}{3}\pi \times 10^5 r^3$

Ratio of volume of atom to that of nucleus $= \dfrac{\frac{4}{3}\pi \times 10^{15} r^3}{\frac{4}{3}\pi r^3} = 10^{15}$

(b) If the atom is represented by the planet earth ($R_e = 6.4 \times 10^6$ m) then the radius of the nucleus would be $r_n = \frac{R_e}{10^5}$; $r_n = \frac{6.4 \times 10^6 \text{ m}}{10^5} = 6.4 \times 10$ m = 64 m

Q.5 In the Gold foil experiment of Geiger and Marsden, that paved the way for Rutherford's model of an atom, $\approx 1.00\%$ of the α-particles were found to deflect at angles > 50°. If one mole of α-particles were bombarded on the gold foil, compute the number of α-particles that would deflect at angles less than 50°.

Ans. No. of α-particles deviated at angle > 50° = 1%

No. of α-particles deflected at less than 50° = 100 – 1 = 99%

No. of α-particles bombarded = 6.022×10^{23}

No. of α-particles the deflected at an angle less than 50°

$$= \frac{99}{100} \times 6.022 \times 10^{23} = \frac{596.175}{100} \times 10^{23} = 5.96 \times 10^{23}$$

CONCEPT APPLICATION LEVEL - III

SECTION - A

Q.1 A radioactive element $_{90}R^{232}$ emits one alpha (α) particle and then two beta (β) particles. The daughter element will have **[NSETS (Stage-1) 2012-13]**

(A) Atomic no 90, Mass No. 228 (B) Atomic no. 90, Mass no. 232

(C) Atomic no. 88, Mass No. 228 (D) Atomic no. 88, Mass no. 232

Q.2 The last electron of the element of atomic member 31 will have the following quantum numbers **[NSETS (Stage-1) 2012-13]**

	n	*l*	m	s
(A)	3	0	0	–1/2
(B)	3	1	1	+1/2
(C)	4	1	–1	–1/2
(D)	4	0	0	+1/2

Q.3 In photoelectric effect, the maximum kinetic energy (E_K) of photoelectrons depends on frequency (f) of light incident on a metal surface of work function (ϕ). In an experiment f is varied and E_K is measured, To determine value for plank's constant (h) **[NSETS (Stage-1) 2013-14]**

(A) Plot E_K against ϕ and find intercept of best fitted line.

(B) Plot E_K against f and find slope of line of best fit.

(C) Plot E_K against ϕ and find slope of line of best fit.

(D) Plot E_K against f and find intercept of best fitted line.

Q.4 Which of the following combinations of elements of given atomic numbers can lead to a compound with a chemical formula of XY_3 ? **[INJSO (Stage-2) 2009]**

(A) 2 and 6 (B) 5 and 15 (C) 3 and 18 (D) 13 and 17

Q.5 Which conclusion was a direct result of the gold foil experiment? **[INJSO (Stage-2) 2009]**

(A) An atom is mostly empty space with a dense, positively charged nucleus.

(B) An atom is composed of at least three types of subatomic particles.

(C) An electron has a positive charge and is located inside the nucleus.

(D) An electron has properties of both waves and particles.

Q.6 The ratio of the radius of the atom to the radius of the nucleus is typically. **[INJSO (Stage-2) 2013]**

(A) 10 (B) 10^2 (C) 10^5 (D) 10^8

Q.7 On adding a neutron to the nucleus of an atom, change will be observed in its **[NTSE Raj. (Stage-1) 2005]**

(A) atomic number (B) mass number
(C) electronic configuration (D) chemical properties

Q.8 K, L and M shells of an atom have 2, 8 and 5 electrons respectively. The number of electrons in its p-orbitals is - **[NTSE Raj. (Stage-1) 2005]**

(A) 6 (B) 7 (C) 8 (D) 9

Q.9 Isotopes of an element have – **[NTSE Raj. (Stage-1) 2013]**

(A) Same Physical Properties (B) Different Chemical Properties
(C) Different No. of Neutrons (D) Different Atomic Number

Q.10 Which of the following is correct electronic configuration of Argon – **[NTSE Raj. (Stage-1) 2013]**

(A) 2, 8 (B) 2, 8, 8 (C) 2, 8, 1 (D) 8, 2, 8

Q.11 Neutronless neutral atom is **[NTSE Raj. (Stage-1) 2014]**

(A) H (B) He (C) Na (D) K

Q.12 **Assertion (A) :** Aluminium foil cannot be used in α-scattering experiment.
Reason (R) : Aluminium is highly malleable metal. **[NTSE Raj. (Stage-2) 2016]**

(A) Both A and R are correct R is the correct reason for A.
(B) Both A and R are correct but R is not the correct reason for A.
(C) A is correct and R is incorrect.
(D) A is incorrect and R is correct.

Q.13 An atom of an element (X) has its K, L and M shells filled with same electron. It reacts with sodium metal to form a compound NaX. The number of electrons in the M shell of the atom (X) will be **[NTSE (Stage-1) 2014]**

(A) Eight (B) Seven (C) Two (D) ONe

Q.14 Number of valence electron in Cl atom is **[NTSE (Stage-1) 2016]**

(A) 16 (B) 7 (C) 17 (D) 18

Q.15 Which of the following has the maximum number of unpaired electrons? **[NTSE (Stage-2) 2014-15]**

(A) Ti^{3+} (B) V^{3+} (C) Fe^{2+} (D) Fe^{3+}

Q.16 In which of the following series of transition metal ions, all metal ions have $3d^2$ electronic configuration **[NTSE (Stage-2) 2014-15]**

(A) Ti^{+}, V^{4+}, Cr^{6+} Mn^{7+} (B) Ti^{3+}, V^{2+}, Cr^{3+}, Mn^{4+}
(C) Ti^{2+}, V^{3+}, Cr^{4+} Mn^{5+} (D) Ti^{4+}, V^{3+}, Cr^{2+} Mn^{3+}

Q.17 What are the values of the quantum number of 19th electron of scandium (Z = 21)? **[NTSE A.P. (Stage-1) 2014]**

(A) $n = 4, l = 0, m = 0, m_s = +\frac{1}{2}$ (B) $n = 4, l = 1, m = 0, m_s = +\frac{1}{2}$

(C) $n = 4, l = 2, m = 1, m_s = +\frac{1}{2}$ (D) $n = 4, l = 3, m = 2, m_s = +\frac{1}{2}$

Q.18 How many number of protons and electrons are present in Ca^{+2}? **[NTSE A.P. (Stage-1) 2014]**

(A) 20 protons; 20 electrons (B) 20 protons; 22 electrons

(C) 18 protons; 18 electrons (D) 20 protons; 18 electrons

Q.19 Which of the following is a B^+ emitter? **[NTSE Bihar (Stage-1) 2014-15]**

(A) ${}^{49}_{20}Ca$ (B) ${}^{8}_{5}B$ (C) ${}^{208}_{82}Pb$ (D) ${}^{94}_{36}Kr$

Q.20 What are the electronic configuration of Na^+ and Cl^- ions? **[NTSE Delhi (Stage-1) 2014]**

(A) Na^+ = 2, 8, 1 and Cl^- = 2, 8, 7 (B) Na^+ = 2, 8 and Cl^- = 2, 8, 8

(C) Na^+ = 2, 8, 2 and Cl^- = 2, 8, 6 (D) Na^+ = 2, 8 and Cl^- = 2, 8, 7

Q.21 Which is the symbol of tungsten? **[NTSE Delhi (Stage-1) 2014]**

(A) Ta (B) Tc (C) W (D) V

Q.22 The electronic configuration of an ion M^{+2} is 2, 8, 14. If its mass is 56, the number of neutrons in its nucleus is **[NTSE Delhi (Stage-1) 2014]**

(A) 30 (B) 32 (C) 34 (D) 42

Q.23 Structure of nuclei of three atoms A, B and C are given below **[NTSE Delhi (Stage-1) 2012]**

A has 90 protons and 146 neutrons

B has 92 protons and 146 neutrons

C has 90 protons and 148 neutrons

Based on the above data, which of these atoms are isotopes and which are isobars?

(A) A and C are isotopes; B and C are isobars

(B) A and B are isotopes; A and C are isobars

(C) B and C are isobars; A and B are isotopes

(D) A and C are isotopes; A and B are isobars

Q.24 Which of the following will have equal number of electrons? **[NTSE Gujarat (Stage-1) 2017]**

(A) Cl^- and Br^- (B) Na^+ and Mg^{+2} (C) Ar and Ne (D) Mg^{+2} and Ca^{+2}

Q.25 How many electrons are there in chloride ion? **[NTSE Gujarat (Stage-1) 2017]**

(A) 17 (B) 18 (C) 16 (D) 8

Q.26 What is electronic configuration of sulphur? **[NTSE Gujarat (Stage-1) 2015]**
(A) 2, 6, 8 (B) 2, 4, 6 (C) 2, 8, 6 (D) 2, 6, 4

Q.27 An ion M^{2+} contains 10 electrons and 12 neutrons. What is the atomic number and mass number of element M? **[NSO - 2011 (14th)]**
(A) 10, 24 (B) 10, 22 (C) 12, 24 (D) 12, 22

Q.28 Two particles X and Y have the composition as shown in the table. The particles X and Y are **[NSO 2011 (15th)] (Set-A)**

Particle	Number of electrons	Number of neutrons	Number of protons
X	10	8	8
Y	18	18	17

(A) Metal atoms (B) Non-metal atoms (C) Negative ions (D) Positive ions

Q.29 Which element has the greatest number of electrons in the outermost shell (energy level) of its atoms? **[NSO - 2012 (15th)] (Set-B)**
(A) Fluorine (B) Helium (C) Lithium (D) Potassium

Q.30 An element L has 9 protons and its valency is l. Another element M has valency 3 and 5. What is the difference in the number of electrons in Land M? **[NSO - 2013 (16th)] (Set-A)**
(A) 6 (B) 5 (C) 4 (D) 3

Q.31 In Rutherford's a particles scattering experiment, a very small fraction of a -particles were deflected by 180°. What did he conclude from this observation? **[NSO - 2013 (16th)] (Set-A)**
(A) All the positive charge and mass of the atom occupy very little space.
(B) Most of the space inside the atom is empty.
(C) All the positive charge and mass of the atom were concentrated in a very small volume
(D) Both A and B.

Q.32 Study the table carefully and select the correct statement. **[NSO - 2014 (17th)] (Set-A)**

Element	Number of protons	Number of neutrons	Number of electrons
U	11	12	10
V	20	20	20
W	16	18	18
X	20	19	18
Y	14	15	18
Z	10	10	10

(A) W IS a noble gas. (B) X and Y are cations.
(C) U and V are anions (D) Z is the lightest element while V is the heaviest.

Q.33 The nucleon number of atom X is 37. It exists as a diatomic molecule, X_2. One molecule of X_2 contains 34 protons. How many neutrons are present in the nucleus of atom X? **[NSO - 2014 (17th)] (Set-A)**

(A) 17 (B) 20 (C) 21 (D) 25

Q.34 Some statements about the Rutherford 's α-particle scattering experiment are given

I. As most of the α particle passed through the gold foil without getting deflected, the positive charge of the atom occupies the entire space.

II. As very few particles were deflected from their path, very little space inside the atom is empty.

III. As a very small fraction of α-particles were deflected by 1800 , all the positive charge and mass of the gold atom were concentrated in a very small volume within the atom.

Select the correct statement(s). **[NSO - 2014 (17th)] (Set-B)**

(A) I and II (B) I and III (C) II and III (D) III only

Q.35 Elements A, B, C, D have atomic numbers as 35, 19, 17, 9 respectively. Choose the odd element. **[NTSE Maharashtra (Stage-1) 2016-17]**

(A) A (B) B (C) C (D) D

Q.36 X and Y are the two atomic species

	X	Y
Number of Proton	8	8
Number of Neutron	8	10

Select the correct statement about X and Y **[NTSE Maharashtra (Stage-1) 2016-17]**

(A) X and Y are isobars (B) X and Y have different chemical properties

(C) X and Y have different Physical properties (D) X and Y the atoms of different elements

Q.37 How many electrons are present in M-shell of an element with atomic number 20? **[NTSE Maharashtra (Stage-1) 2016-17]**

(A) 8 (B) 6 (C) 18 (D) 2

Q.38 Which of the following isotopes of uranium is unstable? **[NTSE Uttar Prasesh (Stage-1) 2014]**

(A) U-234 (B) U-235 (C) U-238 (D) All of the above

Q.39 An element have atomic number 19 and mass number 39. The number of neutron is its nucleus is **[NTSE Uttar Prasesh (Stage-1) 2014]**

(A) 20 (B) 58 (C) 19 (D) 39

Q.40 The ascending order of e/m (charge/mass) value for electron (e), proton (p), neutron (n) and alpha (α) particle is **[NTSE West Bengal (Stage-1) 2015]**

(A) e, p, n, α (B) n, p,e, α (C) n, α, p, e (D) n, p, α, e

SECTION - B

Q.1 An atom consists of an extremely small and dense nucleus and an extranuclear space. The nucleus contains positively charged protons, neutral neutrons and these particles are collectively called nucleons. In the extranuclear space negatively charged electrons revolve around the nucleus. A region of space around the nucleus of the atom where the electron is most likely to be found is called an orbital. In an atom a large no. of electron orbitals are present. These orbitals are designated by a set of numbers known as quantum numbers. These quantum numbers describe electronic configuration, energy of an electron in the atom, size, shape and orientation of the electron orbital. An element has 2K , 8L, 13M and 1N electrons. **[INJSO (Stage-2) 2011]**

(a) Identify the element and write its electronic configuration using Aufbau Principle. **(1.5 marks)**

(b) How many sub shells, orbitals and unpaired electrons it has? **(1.5 marks)**

(c) How many electrons have $l = 1$ and $l = 2$? **(1 mark)**

(d) How many electrons in d sub shell have m = 0 in the given element ? **(0.5 mark)**

(e) How many orbitals are possible in 4th energy level of the given element? **(0.5 mark)**

ANSWER KEY

CONCEPT APPLICATION LEVEL - II

SECTION-A

Q.1	A	Q.2	B	Q.3	A	Q.4	B	Q.5	A	Q.6	D	Q.7	A
Q.8	A	Q.9	C	Q.10	D								

CONCEPT APPLICATION LEVEL - III

SECTION-A

Q.1	A	Q.2	C	Q.3	B	Q.4	D	Q.5	A	Q.6	C	Q.7	B
Q.8	D	Q.9	C	Q.10	B	Q.11	A	Q.12	B	Q.13	B	Q.14	B
Q.15	D	Q.16	C	Q.17	A	Q.18	D	Q.19	B	Q.20	B	Q.21	C
Q.22	A	Q.23	A	Q.24	B	Q.25	B	Q.26	C	Q.27	C	Q.28	C
Q.29	A	Q.30	A	Q.31	C	Q.32	D	Q.33	B	Q.34	D	Q.35	B
Q.36	C	Q.37	A	Q.38	D	Q.39	A	Q.40	C				

SECTION - B

Q.1 (a) $Cr = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

(b) Sub-shells =7 ; orbitals = 15 ; unpaired electrons = 6

(c) no. of electrons having l = 1(p-sub-shell) is 12

no. of electrons having l = 2(d-sub-shell) is 5

(d) no. of electrons in d-subshells having m = 0 is 1

	1	1	1	1	1
m =	–2	–1	0	+1	+2

(e) Number of orbitals present in a shell = n^2 or $(4)^2$ = 16 orbitals