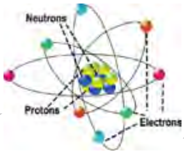



Chapter - 4

# Structure of Atom

## CONCEPT MAPPING

### STRUCTURE OF ATOM

**ATOM**

**Electron**
- Thomson (discovery)
- From cathode rays
- $-1.6 \times 10^{-19}$ C (charge)
- $9.1 \times 10^{-31}$ kg (mass)

**Proton**
- Goldstein (discovery)
- Anode rays or canal rays
- $+1.6 \times 10^{-19}$ C (charge)
- $1.673 \times 10^{-27}$ kg (mass)

**Neutron**
- Chadwick (discovery)
- $\alpha$ particles on lighter elements
- Neutral
- $1.673 \times 10^{-27}$ kg (mass)

ATOMIC MODELS

**Thomson's Atomic model**
- Watermelon model
- Electrons embedded in positive sphere

**Rutherford's Atomic Model**
- Atom has maximum empty space
- Positive charge occupies less space
- Nucleus is very small

**Bohr's Atomic Model**
- Distribution of electrons in shells
- Rule of $2n^2$
- Valence Shells have Valence electrons
- K, L, M, N shells

ATOM

Atomic Number
⇩
No. of protons
or
No. of electron

Atomic Mass
⇩
No. of protons
+
No. of Neutrons

**Isotopes:**
- Same At No.
- Diff Mass No.

**Isobars:**
- Same Mass No.
- Diff. Atomic No.

*John Dalton considered atom to be an indivisible entity, but his concept had to be discarded at the end of nineteenth century, when scientists through experiments were able to find existence of charged (electrons and protons) and neutral particles (neutrons) in the atom. These particles were called the 'Sub-atomic particles'.*

## Discovery of Electrons - Cathode Rays (By J.J. Thomson)

Thomson explained presence of electrons by cathode rays experiment.

**Facts about Electrons**

- Charge on electron = $-1.6 \times 10^{-19}$ C (C = Coloumb)
  (As calculated by Robert E. Millikan)
- Mass of electron = $9.1 \times 10^{-31}$ kg

## Discovery of Protons - Anode Rays/Canal Rays (By E. Goldstein)

E. Goldstein by his famous anode rays/canal rays experiment was able to detect presence of positively charged particles called protons in the atom.

**Facts about Protons**

- Charge on proton = $+1.6 \times 10^{-19}$ C
- Mass of proton = $1.673 \times 10^{-27}$ kg
  *i.e.,* Mass of proton = 1840 x Mass of electron

## Discovery of Neutrons (By J. Chadwick)

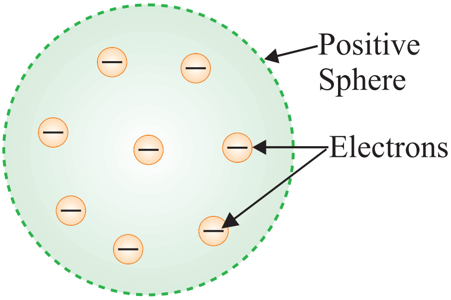
- J. Chadwick bombarded lighter elements (like lithium, boron etc.) with $a$-particles and observed emission of new particles having zero charge but having mass equal to that of proton.
- These particles were called 'Neutron' *i.e.,* neutral particle of the atom.
- Neutron are absent in Protium isotope of hydrogen atom. (${}_1H^1$)
- Since, mass of electron is negligible as compared to that of proton and neutron, sum of masses of protons and neutrons in an atom will compose its atomic mass.

## Atomic Models

- From the knowledge of existence of subatomic particles viz., electron, proton and neutron in an atom, various atomic models were proposed by different scientists.
- Following are some of the atomic models :
  - (a) Thomson's Model of Atom
  - (b) Rutherford's Model of Atom
  - (c) Bohr's Model of Atom
- The most trusted and scientifically established model of atom which is adopted these days is 'Quantum Mechanical Model of Atom'. It will be dealt in higher classes.

**Thomson's Atomic Model**

- This model is often called the 'Watermelon Model'.
- In this model, Thomson predicted the presence of electrons inside positive sphere (made up of protons), just same as seeds of watermelon are embedded in red edible part of watermelon.



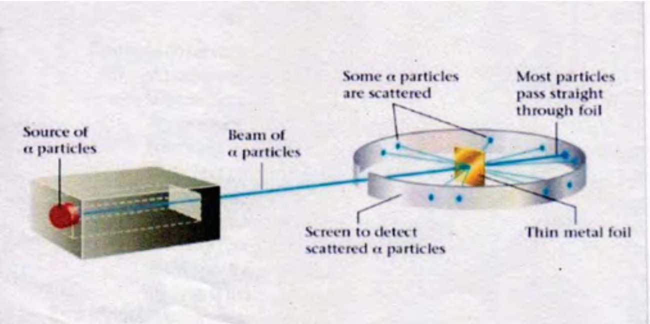

**J. J. Thomson's Model of Atom**

- Although this model explained neutrality of atom, it was not able to explain other scientific experiments conducted on atom. Hence it was discarded.

**Rutherford's Atomic Model**

- In his famous '$a$- particle Scattering Experiment', Rutherford bombarded $a$- particle (Helium nucleus $_2He^4$) upon thin gold foil.

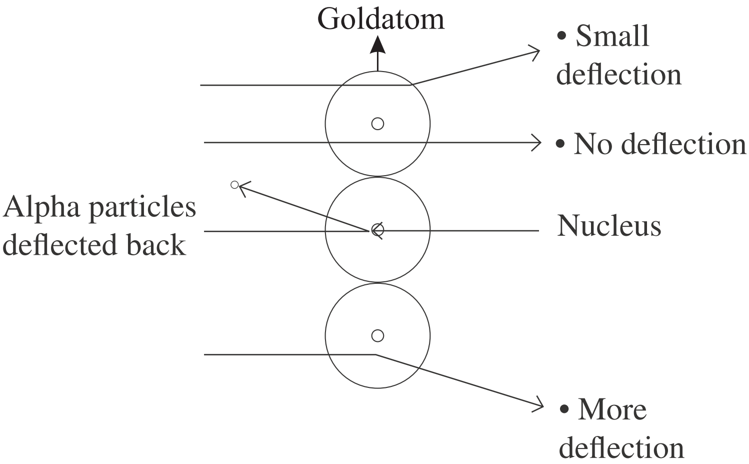
**Rutherford made following observations from this experiment:**




(i) Most of $a$-particles passed through gold foil undeflected.

(ii) Some of the $a$-particles deflected by foil by small angles.

(iii) One out of every 12000 particles appeared to rebound.




Rutherford's α-ray Scattering Experiment

- **From his observation, Rutherford had drawn following conclusions:**

  (i) Atom consists of predominantly empty space as most of $a$-particles passed through gold foil undeflected.

  (ii) Atom contains centrally placed positively charged nucleus (carrying positively charged particles), because few alpha particles were deflected and very few *i.e.,* one in 12000 bounced back.

(iii) Since a minute fraction of *a*-particles suffered deflections and very few bounced back, this led to conclusion that most of the space in an atom is empty and the space occupied by nucleus is negligible compared to in this empty space.

Size of nucleus was about $10^{-5}$ times that of size of atom.

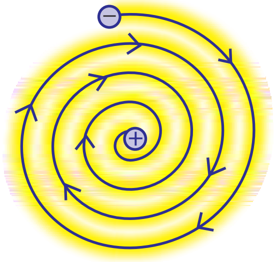
Volume of nucleus = $10^{-5}$ x volume of atom

(iv) Whole of the atomic mass is concentrated in the nucleus.

- **On the basis of his experiment, Rutherford proposed model of an atom having following features :**
  - (i) There is positively charged centre in an atom called nucleus. Nearly all the mass resides in nucleus (Proton + Neutron).
  - (ii) Electrons revolve round the nucleus in well defined orbits.
  - (iii) Size of nucleus is very small compared to the size of atom.

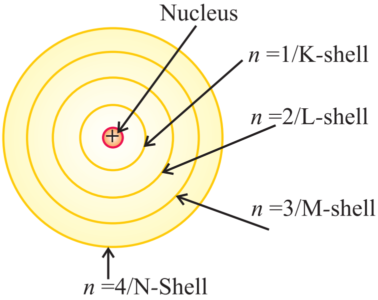
**Drawbacks of Rutherford's Model (Unstability of Atom)**

- According to Rutherford, electrons revolve round the nucleus in well-defined orbits, but electrons being charged particles will lose their energy and finally fall into the nucleus. This will make atom highly unstable.
- This was the major drawback of Rutherford which was unexplained by him.

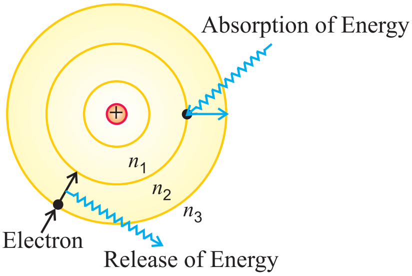


**Bohr's Atomic Model**

- To overcome drawbacks of Rutherford's Model, Neils Bohr in 1912 proposed modified model of structure of atom. He made following assumptions :
  - (i) Only certain special orbits known as discrete orbits of electrons are allowed inside the atom.
  - (ii) While revolving in discrete orbits, the electrons do not radiate energy.
  - (iii) Energy is emitted or absorbed by an atom only when an electron moves from one orbit to another.




**Energy levels in Atom**
**Bohr's Model**




**"Electron's Energy Change"**

## Atomic Number

The total number of protons lying in the nucleus of any atom is called the atomic number.

- An atomic number is the identity of an atom, changing atomic number means changing the atom.
- Atomic number is denoted by 'Z'. (Z=no. of Proton)
- For a neutral atom, no. of protons and electrons are equal.

## Mass Number

It is the sum of total number of protons and neutrons lying in the nucleus of an atom.

Mass Number = **Number of Protons + Number of Neutron**

It is denoted by 'A'. ($A = n_p + n_N$)

**Representation of Atom :** Mass no. → A, Atomic no. → Z: $^{A}_{Z}E$ (E = Symbol of element)

*E.g.,* $^{27}_{13}Al$ (z) Atomic No. of Aluminium (A*l*) = 13 ($Z = n_p$)
(A) Mass No. of Aluminium (A*l*) = 27 ($A = n_p + n_N$)
↓ ↓
(A=13+14)

**Example.** *Calculate number of protons, electrons and neutrons for :*

(a) $^{35}_{17}Cl$ (b) $^{23}_{11}Na$

**Solution :** (a) $^{35}_{17}$Cl (b) $^{23}_{11}$Na

$_zCl = 17\ (n_p)$

Here, since Cl is neutral, so $n_e = n_p = 17$.

Now, Cl = 35

Or $35 = n_p + n_N$

Or $35 = 17 + n_N$

Or $n_N = 35 - 17 = 18$

(b)

$_ZNa = 11$

$n_p = n_e = 11$

$Na = 23$

$23 = n_p + n_N$

$23 = 11 + n_N$

$n_N = 23 - 11 = 12$

## Distribution Of Electrons In Various Shells

The distribution of electrons in various shells is done in accordance to 'Bohr-Bury Scheme'.

**Bohr-Bury Scheme**

This scheme can be summarized as follows :

(i) The filling of electrons in an atom is done in accordance to '$2n^2$', where '*n*' is the number of shell and '$2n^2$' represents the total number of electrons that can be accommodated in that particular shell.

If $n = 1$, *i.e.,* K = shell, $2n^2 = 2 \times (2)^1 = 2$ electrons
If $n = 2$, *i.e.,* L = shell, $2n^2 = 2 \times (2)^2 = 8$ electrons
If $n = 3$, *i.e.,* M = shell, $2n^2 = 2 \times (3)^2 = 18$ electrons
If $n = 4$, *i.e.,* N = shell, $2n^2 = 2 \times (4)^2 = 32$ electrons

***Maximum number number of electrons that can be filled in particular shell.***

(ii) The outermost shell can't hold more than 8 electrons, while second last shell can't have more than 18 electrons, even though they may have capacity to hold more electrons.

*For example,* in '$_{20}Ca$', the electron distribution will be :

| | K | L | M | N |
|---|---|---|---|---|
| $_{20}Ca$ = | 2 | 8 | 8 | 2 |

But $_{20}Ca$ = 2, 8, 10 is wrong although 'M' shell can contain upto 18 electrons.

(iii) Electrons are not filled in a given shell, unless the inner shells are filled. This means, shells are filled in a step wise manner.

**Some examples :**

(a) $_{19}K = 2, 8, 8, 1$

(b) $_{13}Al = 2, 8, 3$

(c) $_{9}F = 2, 7$

(d) $_{10}Ne = 2, 8$

(e) $_{11}Na = 2, 8, 1$

## "Fundamental Particles in Atom"

| Name of Elements | Symbol | Atomic Number | Number of Electrons | Number of Protons | No. of Neutrons | Atomic Mass | Electronic Configuration | | | | Valency |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | K | L | M | N | |
| **Hydrogen** | H | 1 | 1 | 1 | - | 1 | 1 | - | - | - | 1+, - |
| **Helium** | He | 2 | 2 | 2 | 2 | 4 | 2 | - | - | - | 0 |
| **Lithium** | Li | 3 | 3 | 3 | 4 | 7 | 2 | 1 | - | - | 1+ |
| **Beryllium** | Be | 4 | 4 | 4 | 5 | 9 | 2 | 2 | - | - | 2+ |
| **Boron** | B | 5 | 5 | 5 | 6 | 11 | 2 | 3 | - | - | 3+ |
| **Carbon** | C | 6 | 6 | 6 | 6 | 12 | 2 | 4 | - | - | 4+ |
| **Nitrogen** | N | 7 | 7 | 7 | 7 | 14 | 2 | 5 | - | - | 3- |
| **Oxygen** | O | 8 | 8 | 8 | 8 | 16 | 2 | 6 | - | - | 2- |
| **Fluorine** | F | 9 | 9 | 9 | 10 | 19 | 2 | 7 | - | - | 1- |
| **Neon** | Ne | 10 | 10 | 10 | 10 | 20 | 2 | 8 | - | - | 0 |
| **Sodium** | Na | 11 | 11 | 11 | 12 | 23 | 2 | 8 | 1 | - | 1+ |
| **Magnesium** | Mg | 12 | 12 | 12 | 12 | 24 | 2 | 8 | 2 | - | 2+ |
| **Aluminium** | Al | 13 | 13 | 13 | 14 | 27 | 2 | 8 | 3 | - | 3+ |
| **Silicon** | Si | 14 | 14 | 14 | 14 | 28 | 2 | 8 | 4 | - | 4 |
| **Phosphorus** | P | 15 | 15 | 15 | 16 | 31 | 2 | 8 | 5 | - | 3- |
| **Sulphur** | S | 16 | 16 | 16 | 16 | 32 | 2 | 8 | 6 | - | 2- |
| **Chlorine** | Cl | 17 | 17 | 17 | 18 | 35.5 | 2 | 8 | 7 | - | 1- |
| **Argon** | Ar | 18 | 18 | 18 | 22 | 40 | 2 | 8 | 8 | - | 0 |
| **Potassium** | K | 19 | 19 | 19 | 20 | 39 | 2 | 8 | 8 | 1 | 1+ |
| **Calcium** | Ca | 20 | 20 | 20 | 20 | 40 | 2 | 8 | 8 | 2 | 2+ |

## Valence shell and valence electrons

- From Bohr-Bury scheme, we know that maximum number of electrons which can be accommodated in outermost shell is 8.
- Every element tends to have 8 electrons in its outermost shell, in achieving 8 electrons, i.e. octet an atom can either gain electrons or loose electrons.
- The number of electrons lost or gained by an element in achieving determines its valency.
- Electrons in the outermost shell will be called its Valence electrons.

*For example,*

| S. No. | Element | Electron distribution | Valency | Valence electron |
|---|---|---|---|---|
| 1. | $_{6}C$ | 2, 4 | 4 | 4 |
| 2. | $_{7}N$ | 2, 5 | 3 | 5 |
| 3. | $_{8}O$ | 2, 6 | 2 | 6 |
| 4. | $_{9}F$ | 2, 7 | 1 | 7 |
| 5. | $_{10}Ne$ | 2, 8 | 0 | 8 |
| 6. | $_{11}Na$ | 2, 8, 1 | 1 | 1 |
| 7. | $_{12}Mg$ | 2, 8, 2 | 2 | 2 |
| 8. | $_{20}Ca$ | 2, 8, 8, 2 | 2 | 2 |

- Lighter elements like H and He can fill 1& 2 electrons respectively in their outermost shell.

| S. No. | Element | Electron distribution | Valency |
|---|---|---|---|
| 1. | $_{1}H$ | 1 | 1 |
| 2. | $_{2}He$ | 2 | 0 |

- For elements like Li, Be and B, these elements lose their outermost electrons to achieve 2 electrons in their outermost shell. These elements will have valency in accordance to this act.

| S. No. | Element | Electron distribution | Valency |
|---|---|---|---|
| 1. | $_{3}Li$ | 2, 1 | 1 |
| 2. | $_{4}Be$ | 2, 2 | 2 |
| 3. | $_{5}B$ | 2, 3 | 3 |

# Isotopes :

Isotopes are atoms of the same elements having same atomic number and different mass numbers e.g. Isotope of Hydrogen are: $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$

*E.g.,* Chlorine has two isotopes of mass number 35 and 37 respectively. $^{35}_{17}Cl$ and $^{37}_{17}Cl$.

**Uses of isotopes**

(i) Uranium isotope is used as fuel in nuclear reactor.

(ii) Isotope of cobalt is useful in treatment of cancer.

(iii) An isotope of iodine is used in the treatment of goitre.

(iv) Carbon -14 is used in carbon dating.

**Average atomic mass** is an average of the masses of all the isotopes of the element.

In any mixture of pure chlorine, 75% of $Cl^{35}$ and 25% of $Cl^{37}$ is present.

.: Average atomic mass = 75% of $Cl^{35}$ + 25% $Cl^{37}$

Average atomic mass of chlorine

$$= \frac{75}{100} X\ 35 + \frac{25}{100} X\ 37$$

$$= \frac{3X35}{4} + \frac{1X37}{4} = \frac{105}{4} + \frac{37}{4}$$

$$= \frac{1}{4}(105+37)$$

$$= \frac{1}{4} X142 = 35.5u$$

# Isobars

The atoms of those elements which have the same mass number but different atomic numbers are called isobars. Eg. $^{40}_{20}Ca$ and $^{40}_{18}Ar$ have same mass number and different atomic numbers. $^{24}_{11}Na$ and $^{24}_{12}Mg$ is another examples of isobars.