Chapter - 4

Structure of Atom

CONCEPT MAPPING

STRUCTURE OF ATOM

ATOM

Electron
- Thomson (discovery)
- From cathode rays
- –1.6 x×10^{-19}C (charge)
- 9.1 x 10^{-31}kg (mass)

Proton
- Gold stein (discovery)
- Anode rays or canal rays
- +1.6 x 10^{-19}C (charge)
- 1.673 x×10^{-27}kg (mass)

Neutron
- Chadwick (discovery)
- α particles on lighter elements
- Neutral
- 1.673 x×10^{-27}kg (mass)

ATOM MODELS

Thomson's Atomic model
- Water-melon model
- Electrons present 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 Valency electrons
- K, L, M, N shells

ATOM

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

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

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

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 = -1.6×10^{-19} C (C = Coloumb)
  (As calculated by Robert E. Millikan)
- Mass of electron = 9.1×10^{-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 = 1.673×10^{-24} gm
  i.e., Mass of proton = 1840 x Mass of electron

Discovery of Neutrons (By J. Chadwick)

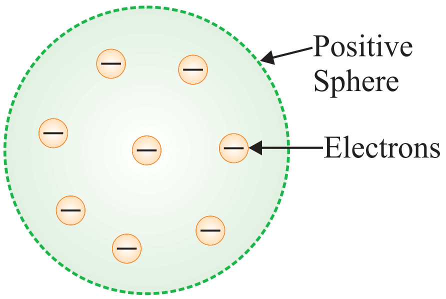
- J. Chadwick bombarded lighter elements (like lithium, boron etc.) with a-particles and observed emission of new particles having zero charge but having mass equal to that of proton.
- These particles were called 'Neutron' *i.e.,* neutral particle of the atom.
- Neutron are absent in Protium isotope of hydrogen atom. ($_1H^1$)
- Since, mass of electrons are negligible as compared to that of proton and neutrons hence, 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 'Water Melon 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.



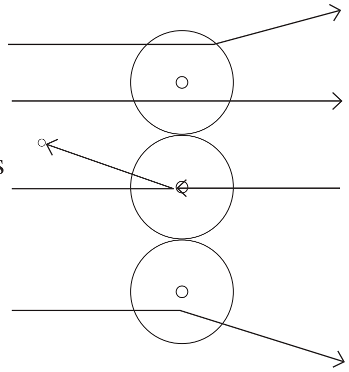
J. J. Thomson's Model of Atom

- Although this model explained neutrality of atom but couldn't able to explain other scientific experiments conducted on atom. Hence it was discarded.

Rutherford's Atomic Model

- In his famous '*a*-ray Scattering Experiment', Rutherford boombarded *a*-ray (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 α-ray Scattering Experiment

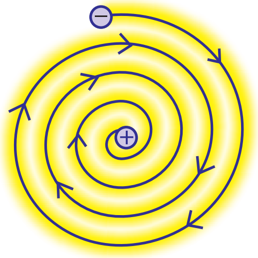
- From his observation, Rutherford draw following conclusions :
  - (i) Atom consists of predominantly empty space as most of *a*-particles passed through gold foil undeflected.
  - (ii) Atom contains centrally placed positively charged nucleus (carrying positively charged particles), because few *a*-particless suffered 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 lead to conclusion that most of the space an atom is empty and the space occupied by nucleus is neigligible compared to this empty space.

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

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

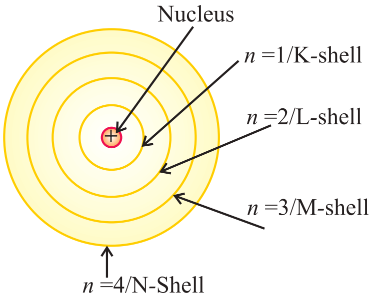
Drawbacks of Rutherford's Model (Unstability of Atom)

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

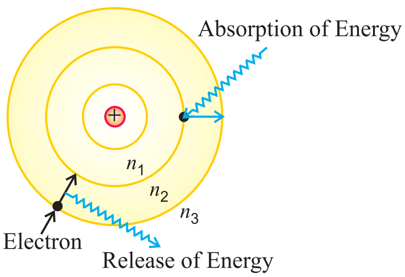


Bohr's Atomic Model

- To overcome drawbacks of Rutherford's Model, Neil 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 proton 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 no. of neutrons lying in the nucleus of an atom.

Mass Number = **No. of proton No. of neutrons**

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

Representation of Atom : $^{A}_{Z}E$ (E = Symbol of element)

E.g., $^{27}_{13}Al$ (z) Atomic No. of Aluminium (Al) = 13 ($z = n_p$)

(A) Mass No. of Aluminium (Al) = 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) $^{35}_{17}Cl$

$_{z}Cl = 17\ (n_p)$

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

Now, $^{A}Cl = 35$

Or $35 = n_p + n_N$

Or $35 = 17 + n_N$

Or $n_N = 35 - 17 = 18$

Distribution Of Electrons In Various Shells

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

Bohr-Burry 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, $2n^2 = 2 \times (2)^2 = 18$ electrons
If $n=4$, *i.e.,* N = shell, $2n^2 = 2 \times (2)^2 = 32$ 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 'Ca_{20}', the electron distribution will be :

	K	L	M	N
Ca_{20}=	2	8	8	2

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

(iii) The outermost shell can't hold more than 2 electrons and the peniultimate shell can't hold more than 8 electrons unless the preceding inner shell (antepenultimate shell) is filled completely obeying '$2n^2$' rule

Some examples :

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

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

(c) $F_9 = 2, 7$

(d) $Ne_{10} = 2, 8$

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

Valence shell and valence Electrons

- From Bohr-Bury sequence, we know that maximum number of electrons which can be accommodated in outermost shell is 8.
- Every element has an urge to have 8 electrons in its outermost shell, in achieving 8 electrons an atom can either gain electrons or loose electrons.
- The number of electrons lost or gained by an element in achieving 8

For example,

S. No.	Element	Electron distribution	Valence
1.	C_6	2, 4	4
2.	N_7	2, 5	3
3.	O_8	2, 6	2
4.	F_9	2, 7	1
5.	Ne_{10}	2, 8	0
6.	Na_{11}	2, 8, 1	1
7.	Mg_{12}	2, 8, 2	2
8.	Ca_{20}	2, 8, 8, 2	2

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

S. No.	Element	Electron distribution	Valence
1.	H_1	1	1
2.	He_2	2	0
3.	Li_3	2, 1	1
4.	Be_4	2, 2	2
5.	B_5	2, 3	3

Isotopes :

Isotopes are atoms of same elements having same atomic number and different mass numbers.

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 rector.

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

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

Relative 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.

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

Relative atomic mass of chlorine

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

$$= \frac{35X3}{4} + \frac{37}{4}$$

$$= \frac{1}{4}(105+34)$$

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

Isobars

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

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS

1. Who discovered electron, proton and neutron?
2. What is the ratio of mass of electron to mass of proton?
3. Mention the charges on electron and proton?
4. What are alpha (*a*) rays?
5. The total number of electrons in Nitrogen are 7. What is its valency?
6. What name is given to pair of atoms such as $^{14}_{7}$N and $^{15}_{7}$N ?
7. Name the subatomic particles present in an atom.