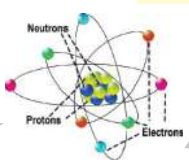


Chapter - 4

Structure of Atom

CONCEPT MAPPING

STRUCTURE OF ATOM

ATOM

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

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

Neutron
- Chadwick (discovery)
- α particles on lighter elements
- Neutral
- 1.673×10^{-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

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

Atomic Mass
⇩
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 x 10^{-19} C (C = Coloumb)
  (As calculated by Robert E. Millikan)
- Mass of electron = 9.1 x 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 x 10^{-19} C
- Mass of proton = 1.673 x 10^{-27} kg
  i.e., Mass of proton = 1840 x Mass of electron

Discovery of Neutrons (By J. Chadwick)

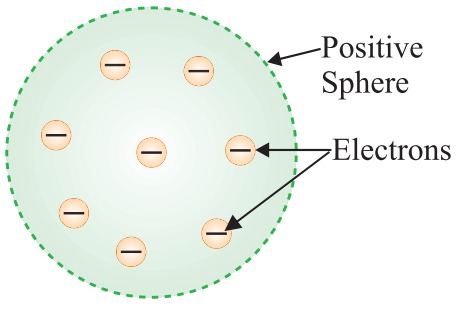
- J. Chadwick bombarded lighter elements (like lithium, boron etc.) with *a*-particles and observed emission of new particles having zero charge but having mass equal to that of proton.
- These particles were called 'Neutron' *i.e.,* neutral particle of the atom.
- Neutron are absent in Protium isotope 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.



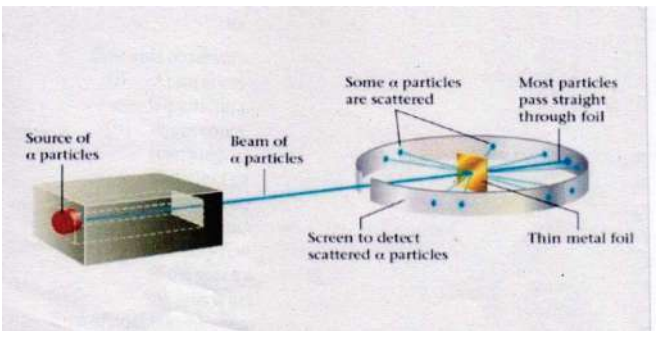
J. J. Thomson's Model of Atom

- 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.

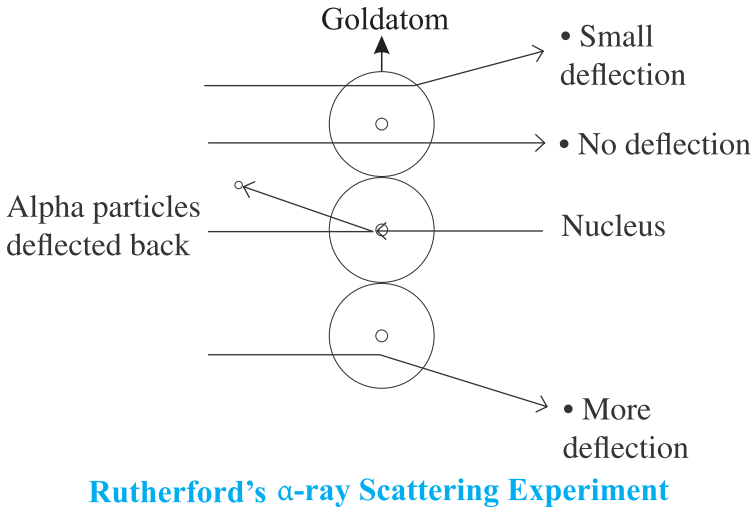
Rutherford made following observations from this experiment:



(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.

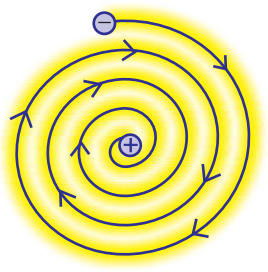
Volume of nucleus = 10^{-5} x volume of atom

(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.

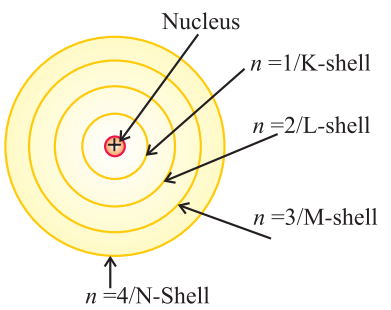
Drawbacks of Rutherford's Model (Unstability of Atom)

- 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.

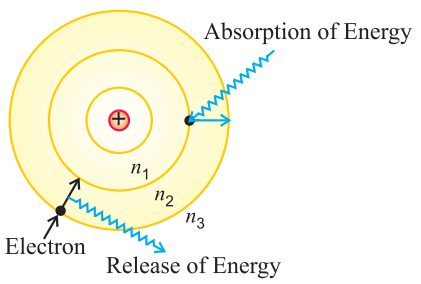


Bohr's Atomic Model

- 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 : $\overset{\text{Mass no.} \rightarrow A}{\underset{\text{Atomic no.} \rightarrow Z}{}}E$ (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) $^{35}_{17}Cl$

$_zCl = 17\ (n_p)$

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

Now, $Cl = 35$

Or $35 = n_p + n_N$

Or $n_N = 35 - 17 = 18$

(b) $^{23}_{11}Na$

$_zNa = 11$

$n_p = n_e = 11$

$Na = 23$

$23 = n_p + n_N$

$23 = 11 + n_N$

$n_N = 23 - 11 = 12$

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.

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS

1. What will happen to an element 'X' if its atoms gain three electrons ?
2. If the electronic configuration of an atom is 2, 8, 2. calculate the total number of electrons in it. Write the name of the atom also.
3. Write any two observation which support the fact that atoms are divisible.
4. Name the particles which determine the mass of an atom.
5. What is the charge on canal rays?
6. What is the difference between Na and Na^+ in terms of electron ?
7. An atom of an element is represented as $^{32}_{16}X$. How many electrons and neutrons are present in this atom ?
8. An atom of an element has 7 electron in its L shell. What is its atomic number and valency ?
9. Which of the following are isotopes and which are isobars?
   Argon, Calcium, Deuterium, Protium.
10. Which subatomic particle has no charge on it?

SHORT ANSWER TYPE QUESTIONS

1. Why is an atom neutral in spite of the presence of charged particles in it?
2. How does a proton differ from an electron?
3. Why do isotopes show similar chemical properties?
4. Differentiate between isotopes and isobars. (any two differences).
5. Write the electronic configuration of Mg^{++}. [at- no. = 12]
6. Describe Thomson's model of atom. Which subatomic particle was not present in Thomson's model of atom?
7. Draw the electron distribution of following elements - (dot structure)
   (a) Na (at no. = 11) (c) Cl (at no. = 17)
   (b) Al (at no. = 13) (d) O (at no. = 8)
8. Is it possible for the atom of an element to have one electron, one proton and no neutron. If so, name the element.
9. Write down the electron distribution of Chlorine atom. How many electrons are there in L-shell? (At no. of chlorine = 17)
10. In the atom of an element 6 electrons are present in the outermost shell. If this atom acquires nobel gas configuration by accepting required number of electrons, then what would be the charge on the ion so formed?

LONG ANSWER TYPE QUESTIOS

1. On the basis of Thomson's atomic model of an atom, explain how the atom is neutral as a whole.
2. What do you think would be the observation, if the *a* particle scattering experiement is carried out using a foil of metal other than gold?
3. Helium atom has an atomic mass of u. It has two protons in its nucleus. How many neutrons does it have?
4. Compare electron, proton and neutron considering their charge, mass and position in an atom.
5. (a) What were the limitations of Thomson's model of atoms?
   (b) What are the limitations of Rutherford's model of an atom.
6. Define valency by taking examples of sodium and chlorine.
7. Mg^{+2} has completely filled K and L shells. Explain what do you understand by this statement.
8. Why do Helium, Neon and Argon have zero valency?
9. Enlist the conclusion drawn by Rutherford from his *a*-Particle scattering experiment.
10. What are the postulates of Bohr's model of an atom?
11. What are isotopes? Give 3 applications of such isotopes.

OBJECTIVE TYPE QUESTIONS:

1. Which of the following correctly represent the electronic distribution in the Mg atom ?
   a) 3, 8, 1 b) 2, 8, 2 c) 1, 8, 3 d) 8, 2, 2
2. Rutherford's 'alpha (*a*) particles scattering experiment' resulted in discovery of
   a) Electron (b) Proton c) Nucleus d) Atomic mass
3. The number of electrons in an element X is 15 and the number of neutrons is 16. Which of the following is the correct representation of the element?
   a. $^{31}_{15}X$
   b. $^{31}_{16}X$
   c. $^{15}_{16}X$
   d. $^{16}_{15}X$
4. Dalton's atomic theory succesfully explained
   i. Law of conservation of mass
   ii. Law of constant proportions
   iii. Law of radioactivity
   iv. Law of multiple proportions
   a. i, ii and iii b. i, iii and iv
   c. i, ii and iv d. only (i)

5. Which of the following statements about Rutherford's model of atom are correct?
   i. considered the nucleus as positively charged
   ii. established that the *a*-particles are four times as heavy as a hydrogen atom
   iii. can be compared to solar system
   iv. was in agreement with Thomson's model
   a. i and iii. b. ii and iv
   c. i and iv. d. only i
6. Which of the following are true for an element?
   i. Atomic number = number of protons + number of electrons
   ii. Mass number = number of protons + number of neutrons
   iii. Atomic mass = number of protons = number of neutrons
   iv. Atomic number = number of protons = number of electrons
   a. i and ii
   b. i and iii
   c. ii and iii
   d. ii and iv
7. The ion of an element has 3 positive charges. Mass number of the atom is 27 and the number of neutrons is 14. What is the number of electrons in the ion?
   a. 13
   b. 10
   c. 14
   d. 16
8. An atom with 3 protons and 4 neutrons will have a valency of
   a. 3 b. 7 c. 1 d. 4
9. The electron distribution in an aluminium atom is
   a. 2, 8, 3. b. 2, 8, 2 c. 8, 2, 3 d. 2, 3, 8
10. Fill in the blanks in the following statements
    a. Rutherford's *a*-particle scattering experiment led to the discovery of the .....
    b. Istopes have same.....but different.....
    c. Neon and chlorine have atomic numbers 10 and 17 respectively. Their valencies will be.....and.....respectively.
    d. The electronic configuration of silicon is.....and that of sulphur is .....
11. Read the following passage and answer the following questions:
    In order to overcome the objections raised against Rutherford's model of an atom, Neils Bohr put forward the following postulates about the model of an atom.
    (i) Only certain special orbits known as discrete orbits have electrons
    (ii) While revolving in discrete orbits the electrons do not radiate energy.

Now complete the following statement

(a) Atoms are made up of _____, _____and_____

(b) _____ amended Rutherford's shortcomings

(c) Electrons do not radiate energy while revolving in _____ orbits.

(d) Discrete orbits are also known as _____

(e) K Shell can accomodate _____ electrons.

Assertion and Reason type Questions :

Directions : In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Mark the correct choice as :

(a) Both assertion (A) and reason (R) are true but reason (R) is the correct explanation of assertion (A).

(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation assertion (A).

(c) Assertion (A) is true but reason (R) is false.

(d) Assertion (A) is false but reason (R) is true.

Q1. Assertion : For noble gases, valency is zero.
Reason : Noble gases have 2or8 valence electrons.
Answer : (a) Noble gases have valency zero because their outer most shells are filled completely.

Q2. Assertion : A few positively charged α – particles are deflected in Rutherfords experiment.
Reason : Most of the Space in the atom is empty.
Answer : (b) The positive charge has to be concentrated in a very small volume (nucleus) that repelled and deflected the positively charged α – particles.