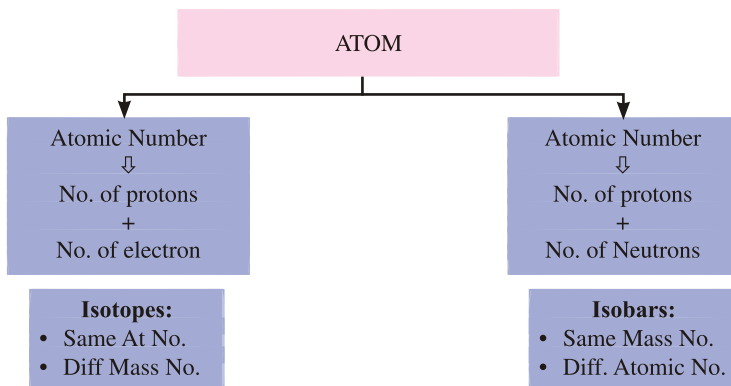
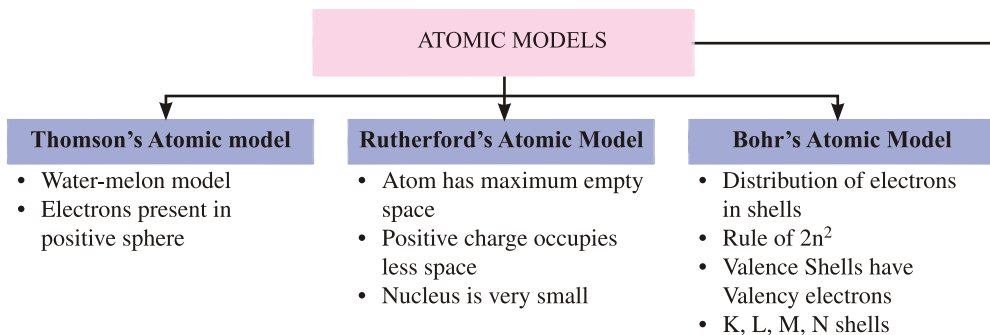
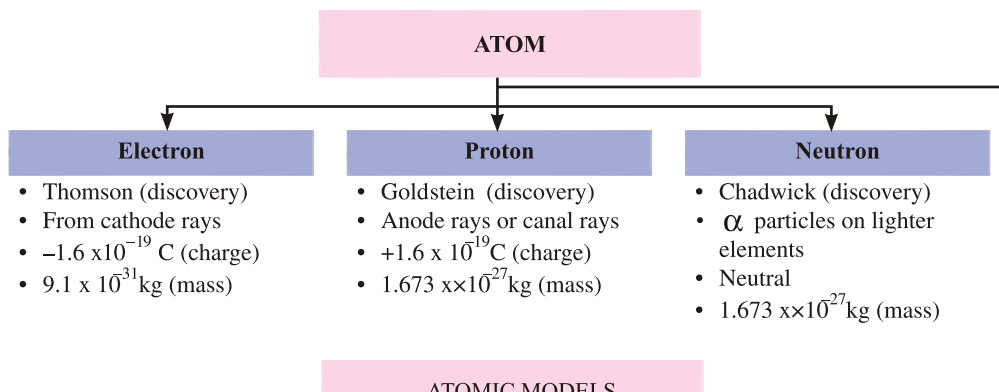


# Chapter - 4

# Structure of Atom

## CONCEPT MAPPING STRUCTURE OF ATOM



*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)**

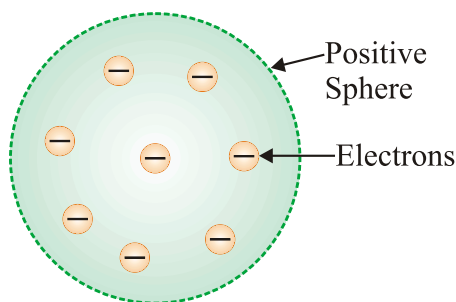
- J. Chadwick bombarded lighter elements (like lithium, boron etc.) with  $\alpha$ -particles and observed emission of new particles having zero charge but having mass equal to that of proton.
- These particles were called 'Neutron' *i.e.*, neutral particle of the atom.
- Neutrons are absent in Protium isotope of hydrogen atom. ( ${}_1\text{H}^1$ )
- 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.

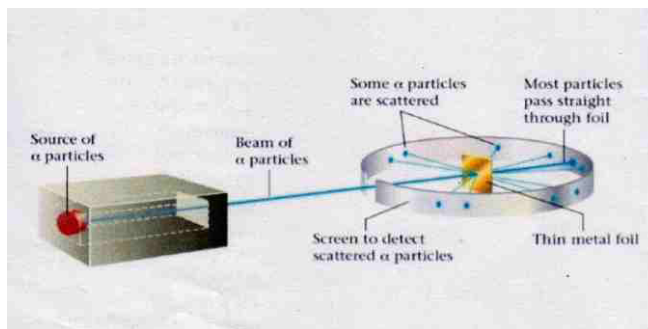


### J. J. Thomson's Model of Atom

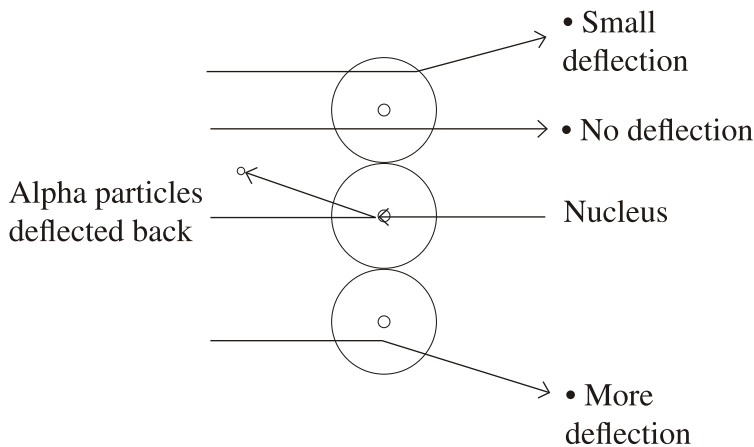
- Although this model explained neutrality of atom but couldn't able to explain other scientific experiments conducted on atom. Hence it was discarded.

## Rutherford's Atomic Model

- In his famous ' $\alpha$ -ray Scattering Experiment', Rutherford bombarded  $\alpha$ -ray (Helium nucleus,  $\text{He}^4$ ) upon thin gold foil.
- Rutherford made following observations from this experiment:
  - (i) Most of  $\alpha$ -particles passed through gold foil undeflected.
  - (ii) Some of the  $\alpha$ -particles deflected by foil by small angles.



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



## Rutherford $\alpha$ -ray Scattering Experiment

- From his observation, Rutherford draw following conclusions :
  - (i) Atom consists of predominantly empty space as most of  $\alpha$ -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  $\alpha$ -particles suffered deflections and very few bounced back, this led to the conclusion that most of the space an atom is empty and the space occupied by nucleus is negligible compared to this empty space.

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

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

- On the basis of his experiment, Rutherford proposed model of atom having following features :

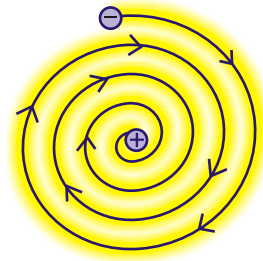
(i) There is positively placed nucleus in an atom. Nearly all the mass resides in nucleus (Proton + Neutron).

(ii) Electrons revolve round the nucleus in well defined orbits.

(iii) Size of nucleus is very small compared to the size of atom.

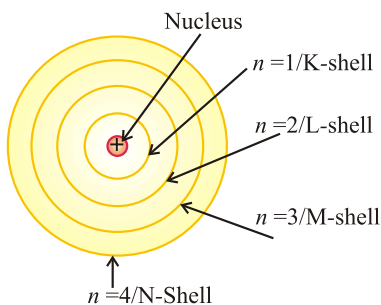
### **Drawbacks of Rutherford's Model (Unstability of Atom)**

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

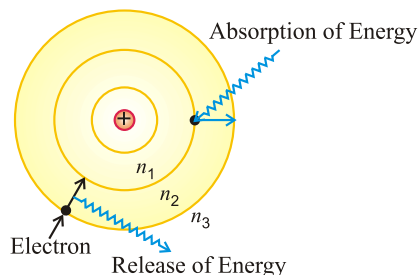


### **Bohr's Atomic Model**

- 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 neutrons lying in the nucleus of an atom.

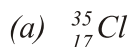
Mass Number = **Number of Proton** + **Number of Neutron**

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 ( $A = n_p + n_N$ )  
 $\downarrow \quad \downarrow$   
 (A=13+14)

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



**Solution : (a)**  ${}_{17}^{35}\text{Cl}$

**(b)**  ${}_{11}^{23}\text{Na}$

$${}_Z\text{Cl} = 17 (n_p)$$

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

Now,  ${}^A\text{Cl} = 35$

Or  $35 = n_p + n_N$

Or  $35 = 17 + n_N$

Or  $n_N = 35 - 17 = 18$

$${}_Z\text{Na} = 11$$

$${}^A\text{Na} = 23$$

$$23 = n_p + n_N$$

$$23 = 11 + n_N$$

$$n_N = 23 - 11 = 12$$

## Distribution Of Electrons In Various Shells

The distribution of electrons in various shells is done in accordance to 'Bohr-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 $n = 1, i.e., K = \text{shell}, 2n^2 = 2 \times (2)^1 = 2$ electrons	} <i>Maximum number number of electrons that can be filled in particular shell.</i>
If $n = 2, i.e., L = \text{shell}, 2n^2 = 2 \times (2)^2 = 8$ electrons	
If $n = 3, i.e., M = \text{shell}, 2n^2 = 2 \times (2)^2 = 18$ electrons	
If $n = 4, i.e., N = \text{shell}, 2n^2 = 2 \times (2)^2 = 32$ electrons	

- (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 ' $\text{Ca}_{20}$ ', the electron distribution will be :

$$\text{Ca}_{20} = \begin{matrix} & \text{K} & \text{L} & \text{M} & \text{N} \\ & 2 & 8 & 8 & 2 \end{matrix}$$

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

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

*Some examples :*

### "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+, -	
Helium	He	2	2	2	2	2	-	-	-	0	
Lithium	Li	3	3	3	4	2	1	-	-	1+	
Beryllium	Be	4	4	4	5	2	2	-	-	2+	
Boron	B	5	5	5	6	2	3	-	-	3+	
Carbon	C	6	6	6	6	2	4	-	-	4+	
Nitrogen	N	7	7	7	7	2	5	-	-	3-	
Oxygen	O	8	8	8	8	2	6	-	-	2-	
Fluorine	F	9	9	9	10	2	7	-	-	1-	
Neon	Ne	10	10	10	10	2	8	-	-	0	
Sodium	Na	11	11	11	12	2	8	1	-	1+	
Magnesium	Mg	12	12	12	12	2	8	2	-	2+	
Aluminium	Al	13	13	13	14	2	8	3	-	3+	
Silicon	Si	14	14	14	14	2	8	4	-	4	
Phosphorus	P	15	15	15	16	2	8	5	-	3-	
Sulphur	S	16	16	16	16	2	8	6	-	2-	
Chlorine	Cl	17	17	17	18	2	8	7	-	1-	
Argon	Ar	18	18	18	22	2	8	8	-	0	
Potassium	K	19	19	19	20	2	8	8	1	1+	
Calcium	Ca	20	20	20	20	2	8	8	2	2+	

- (a)  $K_{10} = 2, 8, 8, 1$
- (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 tend 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 (octet) determine its valency.

Electrons in the outermost shell will be called its Valence electron.

*For example,*

S. No.	Element	Electron distribution	Valency
1.	C <sub>6</sub>	2, 4	4
2.	N <sub>7</sub>	2, 5	3
3.	O <sub>8</sub>	2, 6	2
4.	F <sub>9</sub>	2, 7	1
5.	Ne <sub>10</sub>	2, 8	0
6.	Na <sub>11</sub>	2, 8, 1	1
7.	Mg <sub>12</sub>	2, 8, 2	2
8.	Ca <sub>20</sub>	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 <sub>1</sub>	1	1
2.	He <sub>2</sub>	2	0
3.	Li <sub>3</sub>	2, 1	1
4.	Be <sub>4</sub>	2, 2	2
5.	B <sub>5</sub>	2, 3	3

## Isotopes :

Isotopes are atoms of same elements having same atomic number and different mass numbers e.g. Isotope of Hydrogen.  ${}^1_1\text{H}$ ,  ${}^2_1\text{H}$ ,  ${}^3_1\text{H}$

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

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

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

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

∴ Relative atomic mass = 75% of  $\text{Cl}^{35}$  + 25%  $\text{Cl}^{37}$

Relative atomic mass of chlorine

$$\begin{aligned} &= \frac{75}{100} \times 35 + \frac{25}{100} \times 37 \\ &= \frac{35 \times 3}{4} + \frac{37}{4} \\ &= \frac{1}{4} (105 + 37) \\ &= \frac{1}{4} \times 142 = 35.5\text{u} \end{aligned}$$

## Isobars

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

# 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 and write the name of the atom.
3. Write any two observations 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  $\text{Na}^+$  in terms of electrons.
7. An atom of an element is represented as  $^{\text{X}}$ . How many electrons and neutrons are present in this atom.
8. An atom of an element has 7 electrons 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.
5. Draw the electronic configuration of  $\text{Mg}^{++}$ . [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 X, 6 electrons are present in the outermost shell. If this atom acquires noble gas configuration by accepting requisite number of electrons, then what would be the charge on the ion so formed?

### LONG ANSWER TYPE QUESTIONS

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  $\alpha$  particle scattering experiment is carried out using a foil of metal other than gold?
3. (a) Helium atom has an atomic mass of  $4u$ . It has two protons in its nucleus. How many neutrons does it have?  
(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  $\alpha$ -scattering experiment.
10. What are the postulates of Bohr's model of an atom?

## Ch-4 Structure of the Atom

### Objective Type Questions :

- 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
- Rutherford's 'alpha ( $\alpha$ ) particles scattering experiment' resulted in to discovery of  
a) Electron      (b) Proton      c) Nucleus in the atom      d) Atomic mass
- 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.  ${}_{15}X^{31}$   
b.  ${}_{16}X^{31}$   
c.  ${}_{16}X^{15}$   
d.  ${}_{15}X^{16}$

Dalton's atomic theory succesfully explained

- Law of conservation of mass
  - Law of constant composition
  - Law of radioactivity
  - Law of multiple proportion
  - i, ii and iii
  - i, iii and iv
  - ii, iii and iv
  - i, ii and iv
- Which of the following statements about Rutherford's model of atom are correct?
  - considered the nucleus as positively charged
  - established that the  $\alpha$ -particles are four times as heavy as a hydrogen atom
  - can be compared to solar system
  - was in agreement with Thomson's model
  - i and iii.
  - ii and iii
  - i and iv.
  - only i
- Which of the following are true for an element?
  - Atomic number = number of protons + number of electrons
  - Mass number = number of protons + number of neutrons
  - Atomic mass = number of protons = number of neutrons
  - Atomic number = number of protons = number of electrons
  - i and ii
  - i and iii
  - ii and iii
  - ii and iv
- 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?
  - 13
  - 10
  - 14
  - 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  $\alpha$ -particle scattering experiment led to the discovery of the .....
- b. Isotopes 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, Neil Bohr put forward the following postulates about the model of an atom.
- (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.
- Now complete the following statement
- (a) Atom are made up of \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_
- (b) \_\_\_\_\_ amended Rutherford's shortcomings
- (c) \_\_\_\_\_ do not radiate energy while revolving in \_\_\_\_\_ orbits.
- (d) Discrete orbits are also known as \_\_\_\_\_
- (e) K, Shell can accommodate \_\_\_\_\_ 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 of 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 8 valence electrons.

Answer : (a) Noble gases have valency zero because their shell has 8 valence electrons.

Q2. Assertion : A few positively charged  $\alpha$  – particles are deflected in Rutherford's 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  $\alpha$  – particles.