

Structure of The Atom

Introduction

Matters are made of tiny particles called atom. Atom is made of three particles; electron, proton and neutron. These particles are called fundamental particles of an atom or sub atomic particles.

Electron (e^-) - Electron is denoted by 'e' and is a negatively charged particle. The absolute charge over an electron is equal to 1.6×10^{-19} of negative charge and is considered equal to -1 .

The relative mass of electron is $1/1836$. Since the mass of an electron is very small, thus it is considered equal to 0. Electrons revolve round the nucleus of atoms.

Proton (p^+) - Proton is denoted by 'p' and is positively charged particle. The absolute charge over proton is 1.6×10^{-19} coulomb of positive charge and it is considered as unit positive charge. Thus absolute charge over a proton is equal to $+1$.

The absolute mass of a proton is equal to 1.6×10^{-24} g and considered equal to 1 as it is equal to the mass of 1 hydrogen atom. Proton is present in the nucleus of atom.

Neutron (n) – Neutron is denoted by 'n' and is a neutral particle.

The absolute mass of neutron is 1.6×10^{-24} g. The relative mass of neutron is equal to 1. Neutron is presents in the nucleus of atom.

Nucleus – The centre of atom is called nucleus. Nucleus comprises of neutron and proton. Nucleus of an atom contains the whole mass of an atom.

Discovery of Electron:

In 1897; J. J. Thomson, a British physicist, proposed that atom contains at least one negatively charged particle. Later this particle was named as electron. Thomson called those particles 'corpuscles'.

Discovery of Proton:

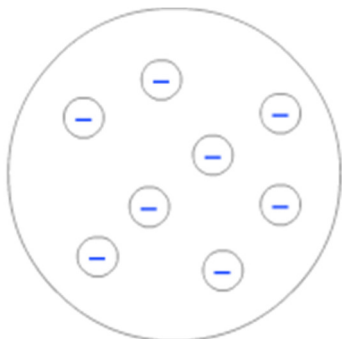
Ernest Goldstein in 1886 discovered the presence of new radiation in gas discharge tube even before the identification of electron. He called these rays as Canal Rays. His experiment led to the discovery of proton.

Discovery of Neutron:

In 1932 J. Chadwick discovered another subatomic particle called neutron. Neutron is present in the nucleus of all atoms.

Thomson's Model of Atom

J. J. Thomson proposed the model of atom similar to a Christmas Pudding or similar to a water melon. His model of atom is generally called plum and pudding model of atom.



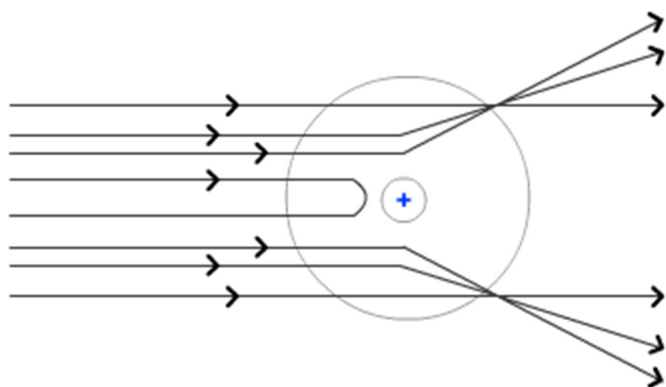
Thomson's Plum Pudding Model

He proposed that electrons are embedded the way black seeds of water melon are embedded; in the sphere of positive charge. According to Thomson

- (a) An atom consists of positively charged sphere in which electrons are embedded.
- (b) The quanta of negative and positive charges are equal. The equal number of negative charge and positive charge makes an atom electrically neutral.

Rutherford's Model of Atom

Ernest Rutherford in 1909 with his team bombarded very thin gold foil with α – particles. He found that



Rutherford's Alpha-ray Experiment

- (a) Most of the α – particles passed without any hindrance.
- (b) Some of the α – particles deflected from their original path at noticeable angle.

(c) Very few of the α – particles bounced back at their original path.

On the basis of his observation, he proposed the model of atom. The Rutherford's Model of Atom is as follows:

(a) Most of the part in an atom is empty.

(b) There is a positively charged center in atom, which contains nearly the whole mass of atom. The centre is called nucleus.

(c) The size of nucleus is very small compared to an atom.

(d) Electrons revolve round the nucleus.

The Rutherford's Experiment is also known as Geiger-Marsden Experiment.

Drawbacks of Rutherford Model

(a) According to Rutherford's Model, electron revolves round the positively charged nucleus which is not expected to be stable. But a charged particle in an accelerated motion along a circular path would lose energy because of radiation and finally would fall into nucleus. This makes an atom unstable while atoms are quite stable.

If atoms were not stable no matter would exist in nature.

(b) Rutherford model could not solve the problem of atomic mass of atom as it proposed only the existence of protons in the nucleus.

However, the problem of atomic mass could be solved after the discovery of neutron.

Bohr's Model of Atom

Neils Bohr, a Danish physicist, in 1913 proposed model of atom which rectified the problems left by Rutherford's Model. He proposed that

(a) Electrons revolve round the nucleus in a fixed orbit.

(b) He called these orbits as 'stationary orbit'.

(c) Each stationary orbit is associated with fixed amount of energy, thus electrons do not radiate energy as long as they keep on revolving around the nucleus in fixed orbit.

The circular path around the nucleus is called orbit, energy level or shell. Energy level are represented by letter – K, L, M, N, and so on.

Therefore,

- 1st orbit is denoted by – K
- 2nd orbit is denoted by – L
- 3rd orbit is denoted by – M, and so on.

The orbits are denoted by 1, 2, 3, and so on.

Distribution of Electrons in Orbit or Shell:

The distribution of electrons in an orbit is obtained by $2n^2$, where 'n' is number of orbit.

Therefore,

Number of electrons in K-shell i.e. in 1st orbit.

Here $n = 1$

Therefore,

$$2n^2 = 2 \times 1^2 = 2$$

Thus, maximum number of electrons in K-shell i.e. 1st shell = 2

Number of electrons in L-shell, i.e. in 2nd orbit

Here $n = 2$, therefore,

$$2n^2 = 2 \times 2^2 = 8$$

Thus, maximum number of electrons in L-shell = 8

Number of electrons in M-shell, i.e. in 3rd orbit

Here $n = 3$, therefore,

$$2n^2 = 2 \times 3^2 = 18$$

Thus, maximum number of electrons in M-shell = 18

Number of electrons in N-shell, i.e. in 4th shell

Here $n = 4$, therefore,

$$2n^2 = 2 \times 4^2 = 32$$

Thus, maximum number of electrons in N-shell = 32

In similar way maximum number of electrons in any shell can be calculated.

Atomic Number

Atomic number is the fundamental properties of an atom. Every atom is identified by its unique atomic number. Atomic number is denoted by 'z'.

Atomic number is equal to the number of protons present in an atom.

Since an atom is electrically neutral, thus number of protons and number of electrons are equal to make an atom electrically neutral.

Atomic number = Number of protons = Number of electrons

Example :-

The atomic number of Hydrogen is 1, helium is 2, lithium is 3, beryllium is 4, boron is 5, carbon is 6, nitrogen is 7, oxygen is 8, etc.

Sample exercise:

(1) Atomic number of calcium is 20. Calculate the number of electrons and protons in calcium.

Solution:

Since, Atomic number = Number of protons = Number of electrons

Therefore,

Number of electrons in calcium = 20

Number of protons in calcium = 20

(2) Number of protons in sodium atom is 11, find the atomic number and number of electrons in a sodium atom.

Solution,

Since, Atomic number = Number of protons = Number of electrons

Therefore,

Atomic number of sodium = 11

Number of electrons in sodium = 11

Mass Number or Atomic Mass

Mass number of an atom is defined as the sum of the number of protons and number of neutrons. Mass number is nearly equal to the atomic mass of an atom. Since, protons and neutrons reside in the nucleus, thus they are also known as nucleons.

This means

Mass number of an atom = Number of protons + Number of neutrons

Example

(1) Atomic mass of aluminium is 27 u and atomic number is 13, find the number of protons and number of neutrons in aluminium.

Solution:

Since,

Atomic number = 13

Therefore, number of proton = 13

We know that, Atomic mass (Mass number) = Number of protons + Number of neutrons

Therefore,

$$27 \text{ u} = 13 + n$$

$$\text{Or, } n = 27 - 13 = 14$$

Therefore, number of proton = 13 and number of neutron = 14

(2) The atomic number of carbon is 6 and number of neutron is equal to 6. Find the atomic mass or mass number of carbon.

Solution:

Since atomic number of carbon = 6

Therefore, number of proton = 6

Now, Atomic mass = number of proton + number of neutron

$$\text{Or, Atomic mass or mass number} = 6 + 6 = 12 \text{ u}$$

Thus, mass number or atomic mass of carbon = 12u

Arrangement of electrons in an atom – Electronic Configuration

The maximum number of electrons can be obtained by $2n^2$; where 'n' is the orbit number. Thus after knowing the maximum number of electrons for a particular shell, the arrangement of electrons in an atom can be identified. It is called Bohr Bury Schemes.

Rules to write the electronic configuration of an atom

- (a) Maximum number of electrons in an orbit is calculated by $2n^2$, where 'n' is number of orbit and may be equal to 1, 2, 3,
- (b) Electrons occupy the next orbit only after filling the inner orbit completely.
- (c) The maximum number of electrons in outermost orbit will not be more than 8.

Electronic configuration of Hydrogen

Atomic number of hydrogen = 1

Therefore number of electrons = 1

Maximum number of electrons in 1st orbit = 2

Since, hydrogen has only one electron, therefore, it will reside in 1st orbit.



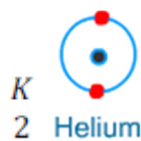
Thus electronic configuration of hydrogen

Number of orbit present in hydrogen = 1

Electronic configuration of Helium

Atomic number of helium = 2

Therefore number of electrons = 2



Therefore, electronic configuration of helium is

Number of orbit in helium atom = 1

Electronic configuration of Lithium

Atomic number of Lithium = 3

Therefore number of electrons = 3

Since the maximum number of electrons in 1st orbit is equal to 2, therefore, after accommodating 2 electrons in 1st orbit, the third electron will go in 2nd orbit.



Thus, electronic configuration of lithium is

Number of orbit in Lithium atom = 3.

Electronic configuration of Beryllium

Atomic number of beryllium = 4.

Therefore number of electrons = 4.



Thus, electronic configuration of Beryllium is

Number of orbit in beryllium = 2

Electronic configuration of Boron

Atomic number of boron = 5

Therefore number of electrons = 5



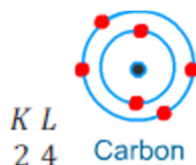
Thus, electronic configuration of boron is

Number of orbit in boron = 2

Electronic configuration of Carbon

Atomic number of carbon = 6

Therefore number of electrons = 6



Thus, electronic configuration of carbon is

2 4

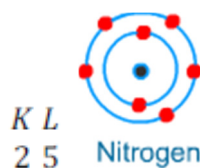
Number of orbit in carbon = 2

Electronic Configuration of Elements - From Nitrogen (N) to Sodium (Na)

Electronic configuration of Nitrogen

Atomic number of nitrogen = 7.

Therefore number of electrons = 7



Thus, electronic configuration of nitrogen is

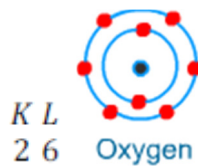
2 5

Number of orbit in nitrogen = 2

Electronic configuration of Oxygen

Atomic number of oxygen = 8.

Therefore number of electrons = 8.



Thus, electronic configuration of oxygen is

2 6

Number of orbit in oxygen = 2

Electronic configuration of Fluorine

Atomic number of fluorine = 9

Therefore number of electrons = 9



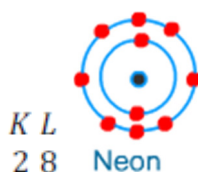
Thus, electronic configuration of fluorine is

Number of orbit in fluorine = 2

Electronic configuration of Neon

Atomic number of neon = 10

Therefore number of electrons = 10



Thus, electronic configuration of neon is

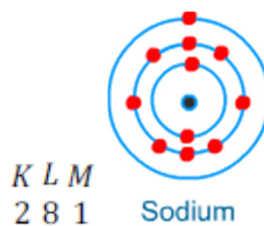
Number of orbit in neon = 2

Electronic configuration of Sodium

Atomic number of sodium = 11

Therefore number of electrons = 11

Since, in 2nd orbit the maximum number of electrons is equal to 8 and there are 11 electrons in sodium atom, thus the eleventh electron will go in third orbit.



Thus, electronic configuration of sodium is

Number of orbit in sodium = 3

Electronic Configuration of Elements - From Magnesium to Calcium

Electronic configuration of Magnesium

Atomic number of magnesium = 12

Therefore number of electrons = 12



Thus, electronic configuration of magnesium is

Number of orbit in magnesium = 3.

Electronic configuration of Aluminium

Atomic number of aluminium = 13.

Therefore number of electrons = 13.



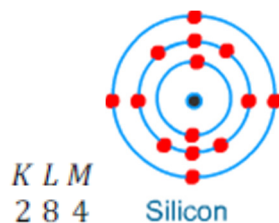
Thus, electronic configuration of aluminium is

Number of orbit in aluminium = 3

Electronic configuration of Silicon

Atomic number of silicon = 14

Therefore number of electrons = 14



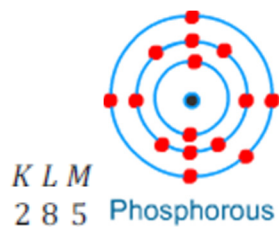
Thus, electronic configuration of silicon is

Number of orbit in silicon = 3

Electronic configuration of Phosphorous (P)

Atomic number of phosphorous = 15

Therefore number of electrons = 15



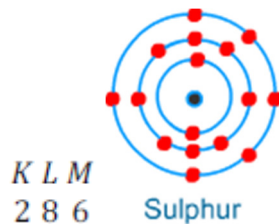
Thus, electronic configuration of phosphorous is

Number of orbit in phosphorous = 3

Electronic configuration of Sulphur (S)

Atomic number of sulphur = 16

Therefore number of electrons = 15



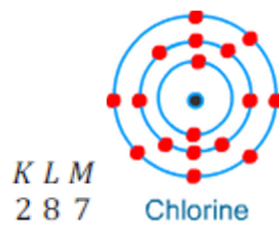
Thus, electronic configuration of sulphur is

Number of orbit in sulphur = 3

Electronic configuration of Chlorine (Cl)

Atomic number of chlorine = 17

Therefore number of electrons = 17



Thus, electronic configuration of chlorine is

Number of orbit in chlorine = 3

Electronic configuration of Argon (Ar)

Atomic number of argon = 18

Therefore number of electrons = 18



Thus, electronic configuration of argon is

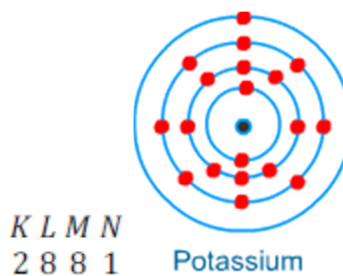
Number of orbit in argon = 3

Electronic configuration of Potassium (K)

Atomic number of potassium = 19

Therefore number of electrons = 19

Since, maximum number of electrons in outermost orbit will not be more than 8, thus the 19th electron of potassium atom will reside in 4th orbit.



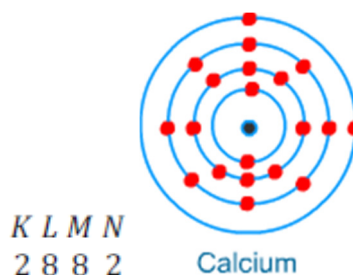
Thus, electronic configuration of potassium is

Number of orbit in potassium = 4

Electronic configuration of Calcium (Ca)

Atomic number of calcium = 20

Therefore number of electrons = 20



Thus, electronic configuration of calcium is

Number of orbit in calcium = 4

Valency

You have read that noble gases have fully filled outermost shell. Due to this, they are stable and they do not react with other elements. Other elements also tend to attain stable configuration by completing the octet in their outermost orbit. This is important to note that, the number of electrons in the outermost orbit of an element is closer to octet. An element can lose or gain electron in order to complete the octet. This tendency of losing or gaining electrons imparts valency to an element.

Let us take example of hydrogen. Hydrogen can readily lose or gain an electron. So, its valency is one. Now, let us take example of Hydrochloric Acid (HCl). One atom of chlorine combines with one atom of hydrogen to form hydrochloric acid. In this case, hydrogen loses one electron and thus gets +1 charge. On the other hand, chlorine gains an electron and thus gets – 1 charge. So, valency of hydrogen and chlorine are one.

Valency can be defined as combining capacity of an atom.

Example : –

Hydrogen molecule - Hydrogen has only one electron in its outermost orbit, thus it requires one more electrons to complete its outermost orbit. Therefore, in order to complete outermost orbit, hydrogen shares one electron with another hydrogen atom and form H₂ (hydrogen molecule).

In the case of LiCl (Lithium chloride) - Lithium has three electrons in its outermost orbit and chlorine has seven electrons in its outermost orbit. Thus in order to make outermost orbit completely filled lithium loses one electrons and chlorine gains one electron. After losing one electron, lithium has two electrons in its outermost orbit and after gaining one electron, chlorine has eight electrons in its outermost orbit. And they form LiCl (Lithium chloride)

Name, Symbol, Atomic number, Number of electrons, Distribution of electrons in shells (electronic configuration) and Valency of some elements (From Hydrogen to Calcium)

Elements	Symbol	Atomic Number	No. of electron	Distribution of electron				Valency
				K	L	M	N	
Hydrogen	H	1	1	1				1
Helium	He	2	2	2				0
Lithium	Li	3	3	2	1			1
Beryllium	Be	4	4	2	2			2
Boron	B	5	5	2	3			3
Carbon	C	6	6	2	4			4
Nitrogen	N	7	7	2	5			3
Oxygen	O	8	8	2	6			2
Fluorine	F	9	9	2	7			1
Neon	Ne	10	10	2	8			0
Sodium	Na	11	11	2	8	1		1
Magnesium	Mg	12	12	2	8	2		2
Aluminium	Al	13	13	2	8	3		3
Silicon	Si	14	14	2	8	4		4
Phosphorous	P	15	15	2	8	5		3
Sulphur	S	16	16	2	8	6		2
Chlorine	Cl	17	17	2	8	7		1
Argon	Ar	18	18	2	8	8		0
Potassium	K	19	19	2	8	8	1	1
Calcium	Ca	20	20	2	8	8	2	2

Isotopes

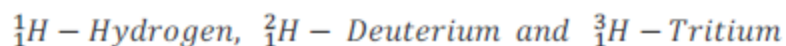
Elements having same atomic number but different atomic masses are known as Isotopes.

Example –

Carbon-12, Carbon-13, Carbon-14 are three isotopes of carbon atom. Here 12, 13 and 14 are the atomic masses of isotopes of carbon respectively. Since, atomic number is the unique property of an atom, thus the atomic number of carbon is 6 even in the case of three types of carbon (isotopes)

Hydrogen -1 , Deuterium – 2, Tritium -3 are three isotopes of hydrogen.

The isotopes of hydrogen are written as:



Use of Isotopes:

Carbon – 14 is used in carbon dating.

An isotope of uranium is used as fuel in nuclear reactor.

An isotope of cobalt is used in treatment of cancer.

An isotope of iodine is used in treatment of goitre.

Isobars:

Atoms having same atomic mass and different atomic numbers are known as Isobars.

Example –

${}_{18}^{40}\text{Ar}$ (*argon*) and ${}_{20}^{40}\text{Ca}$ (*calcium*)

Both the elements have same atomic mass equal to 40 but different atomic numbers, i.e. argon has atomic number equal to 18 and calcium has atomic number equal to 20.