ATOMIC STRUCTURE

Atomic Structure :

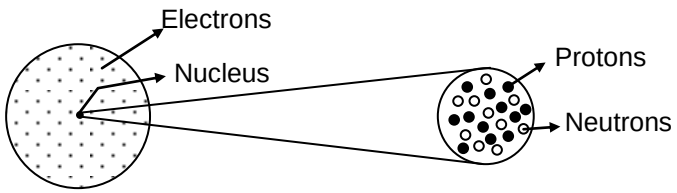
1) Atom is smallest particle of matter which may or may not have independent existence and has capacity to take part in chemical reaction.
2) Atom is divisible, it is made of sub atomic particles called electrons, protons and neutrons.
3) Protons and Neutrons are present at the centre of atom called " Nucleus" .
4) Nucleus has positive charge and total mass of atom is concentrated at the centre.
5) Electrons revolve round the nucleus in circular paths called orbits or shells or energy levels.
6) Protons and Neutrons are collectively called " Nucleons"
7) Nucleus can be called as the Central core of atom.

SUB ATOMIC PARTICLES

Based on Dalton' s atomic theory, an atom is the basic unit of an element that can enter into the chemical combination. According to Dalton, an atom is extremely small and indivisible. But experiments have shown that are visible and also divisible. With the help of the instrument **scanning tunneling microscope** (invented by Gerd Binning and Heinrich Rohrer in 1980 which earned them Noble Prize in 1986) individual atoms can be imaged.

Early in the twentieth century, a series of investigation clearly demonstrated that atoms are actually made up of even smaller particles, which are called subatomic particles. Scientists have discovered a large number of subatomic particles, but protons, neutrons and electrons are the three main subatomic particles that will be discussed in the present topic.

Protons, neutrons and electrons are subatomic particles. At the centre of an atom there exists a very tiny extremely dense core called the **nucleus**. The protons and neutrons of an atom are packed in the nucleus, and are combinely called **nucleons**. The electrons in an atom surround the nucleus and fill the remaining space of the atom as shown below.



The internal structure of an atom

Two of the subatomic particles protons and electrons carry electric charge. Protons carry a single unit of positive charge whereas electrons carry one unit of negative charge. Neutrons have no charge and are said to be electrically neutral. The masses and charges of the subatomic particles are given in the following table.

Atom is made up of sub atomic particles called electrons, protons and neutrons. As already discussed, proton and neutron are present at the centre of atom called " Nucleus" & electron revolves round the nucleus in circular path called orbits

Electron

It is negatively charged sub atomic particle.

- Discovered by J.J.Thomson.
- It' s charge is represented as – 1 .
- It has very negligible mass compared to Proton & Neutron.

Proton

It is positively charged particle of atom.

- It was discovered by Goldstein.
- Its relative charge is represented as + 1.
- Its mass is equivalent to mass of Hydrogen atom.

Neutron

It is a neutral particle of atom

- It was discovered by Jems Chadwick.
- Its relative charge is represented as O.
- Its mass is equivalent to mass of Hydrogen atom.

Particles	Electron	Proton	Neutron
Mass (g)	9.10939×10^{-28} g 0.000548 amu	1.672×10^{-24} g 1.007277 amu	1.675×10^{-24} g 1.008665 amu
Electrical charge	-1.6022×10^{-19} C -4.8×10^{-10} esu	$+1.6022 \times 10^{-19}$ C $+4.8 \times 10^{-10}$ esu	0
Charge unit	-1	+1	0
Symbol	${}_{-1}e^{0}$	${}^{1}_{1}H$, ${}^{1}_{+1}P$	${}^{1}_{0}n$

In the symbols, the subscript and superscript represents the charge and mass of the particles respectively. Two particles with the same electric charge will repel each other and two particles with opposite charges will have an attractive force. In an atom, the negatively charged electrons are attracted to positively charged protons. Because of this attraction nucleus holds the electrons around it. Electrons because of their identical charges repel each other. The repulsion between the electrons keep them spread out throughout the volume of the atom. Protons also repel each other, but they are able to stay together in the small volume of the nucleus because of the presence of strong nuclear force which dominates the repulsive forces between protons.

Matter that we find in the nature is electrically neutral, which means that they contain equal number of positive and negative charges. So atoms contain equal number of protons and electrons and hence atoms are neutral.

SOME IMPORTANT TERMS RELATED TO ATOMIC STRUCTURE

Atomic number (Z)

It is the number of protons in the nucleus of each atom of an element. A neutral atom contains equal number of protons and electrons. So atomic number also indicates the number of electrons present in the atom. Atomic number (Z) = number of protons (P) = number of electrons (e).

The chemical identity of an atom can be determined only from its atomic number. For example: The atomic number of oxygen is 8. This means that neutral oxygen atom has 8 protons and 8 electrons. Or, we can also say that every atom in the universe that contains 8 protons is oxygen.

Mass number (A)

It is the total number of neutrons and protons present in the nucleus of an atom of an element. Except hydrogen, all other nuclides contain both protons and neutrons. Mass number (A) = number of protons + number of neutrons.

$$A = Z + n$$

$$n = A - Z$$

So, the number of neutrons in an atom is equal to the difference between the mass number and atomic number or protons.

The atomic number and mass number of an atom of an element (E or X) is represented as, ${}^{A}_{Z}E$, where A and Z are mass number and atomic number of atom of an element respectively.

Example:

(i) ${}^{16}_{8}O$ represents an atom of element oxygen (O) with atomic number (Z) = 8 and mass number (A) = 16.

(ii) ${}^{17}_{8}O$ represents an atom of element oxygen (O) with atomic number (Z) = 8 and mass number (A) = 17.

Symbol of elements along with their Z and A values

Element	Symbol	Z (Atomic number	A (Mass number)
Hydrogen	H	1	1
Helium	He	2	4
Lithium	Li	3	7
Beryllium	Be	4	9
Boron	B	5	11
Carbon	C	6	12
Nitrogen	N	7	14
Oxygen	O	8	16
Fluorine	F	9	19
Neon	Ne	10	20
Sodium	Na	11	23
Magnesium	Mg	12	24
Aluminium	Al	13	27
Silicon	Si	14	28
Phosphorus	P	15	31
Sulphur	S	16	32
Chlorine	Cl	17	35.5
Argon	Ar	18	40
Potassium	K	19	39
Calcium	Ca	20	40
Scandium	Sc	21	45
Titanium	Ti	22	48
Vanadium	V	23	51

Chromium	Cr	24	52
Manganese	Mn	25	55
Iron	Fe	26	56
Cobalt	Co	27	59
Nickel	Ni	28	59
Copper	Cu	29	63.5
Zinc	Zn	30	65

All atoms of a given element do not have same mass. Most elements exist in nature as mixture of similar atoms which differ in their masses and are called isotopes.

Isotopes

Atoms of an element with the same number of protons but different number of neutrons are called **isotopes**. Isotopes have similar chemical properties. All the properties of isotopes which depend on mass are different.

Example: Hydrogen has three isotopes of names Protium or hydrogen–H, deuterium–D and Tritium–T with mass numbers 1, 2, and 3 respectively. They are represented as,

$^{1}_{1}H$ Hydrogen or Protium (1p, 0 n)

$^{2}_{1}H$ or $^{2}_{1}D$ Deuterium (1p, 1n)

$^{3}_{1}H$ or $^{3}_{1}T$ Tritium (1p, 2n)

Isotopes of some common elements

Element	Isotopes
Carbon	$^{12}_{6}C$, $^{13}_{6}C$, $^{14}_{6}C$
Nitrogen	$^{14}_{7}N$, $^{15}_{7}N$
Oxygen	$^{16}_{8}O$, $^{17}_{8}O$, $^{18}_{8}O$
Chlorine	$^{35}_{17}Cl$, $^{37}_{17}Cl$
Uranium	$^{235}_{92}U$, $^{238}_{92}U$, $^{239}_{92}U$

Isobars

Atoms of different elements having same mass number but different atomic number are called **isobars**. Isobars differ in number of protons and neutrons. Examples are :

(i) $^{40}_{18}Ar$, $^{40}_{20}Ca$

(ii) $^{3}_{1}H$, $^{3}_{2}He$ (isotope of $^{4}_{2}He$)

Isotones

Atoms of different elements having same number of neutrons are called **isotones**.

Examples are

(i) $^{11}_{5}B$, $^{12}_{6}C$

(ii) $^{2}_{1}H$, $^{3}_{2}He$

1. Give the difference between mass number and atomic mass.
2. Find the number of protons, electrons and neutrons in the following species

(a) $^{27}_{13}Al$ (b) $^{40}_{20}Ca$ (c) $^{235}_{92}U$ (d) $^{56}_{26}Fe$

MOLECULAR MASS

Molecular mass of a compound can be calculated from the atomic mass of the constituent elements.

EXAMPLE :- **1) Molecular mass of carbon dioxide** – **CO_2** can be calculated as follows.

Atomic mass of carbon-C = 12amu

Atomic mass of oxygen-O = 16amu

Molecular mass of CO_2 is = 12 + (2 X 16) = 12 + 32 = 44amu

2) Molecular mass of water - **H_2O**

Atomic mass of hydrogen is = 1amu

Atomic mass of oxygen is = 16amu

Molecular mass of water is = (2 X 1) + 16 = 2 + 16 = 18amu

ELECTRONIC CONFIGURATION

The Arrangement of Electrons in Atoms (Electronic Configuration)

The arrangement of electrons in the different shells of an atom is called **electronic configuration.**

The electron shells of an atom are not filled arbitrarily. The number of electrons in a shell follows a set of rules, called the **Bohr-Bury rules.**

Bohr-Bury Rules

Of the various Bohr-bury rules, we need to know the following two in order to write the electronic configuration of elements up to calcium (Z = 20).

(i) **The maximum number of electrons that can be accommodated in a shell is given by $2n^2$, where n is the shell number.**

For example, n = 1 denotes the first (K) shell, and so on. You can easily calculate that the K, L, M, N,… Shells can accommodate a maximum of 2, 8, 18, 32,…. electrons, respectively.

Shell	Value of *n*	Max. number of electrons
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

(ii) The outermost shell of an atom cannot contain more than 8 electrons in any case. A new shell is formed as soon as the outer most shell attain 8 electrons.

(iii) The penultimate shell (last but the one) cannot have more than 18 electrons.

Applying Bohr-Bury rules

(i) By now, it should be clear to you that the only electron in a hydrogen atom ($_1H$) occupies the K-shell, and so do the two electrons in a helium atom ($_2He$).

(ii) As the K shell cannot have more than two electrons (Rule 1), the third electron of the Lithium atom ($_3Li$) must go to the next shell, i.e., the L shell.

(iii) So, the arrangement of electrons in a lithium atom can be shown as $\begin{matrix} K & L \\ 2 & 1 \end{matrix}$. How ever, there is a convention that the names of the shells are not mentioned in electronic configuration.

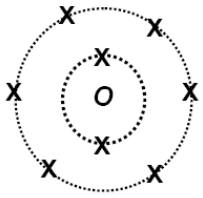
(iv) The order in which the numbers of electrons are mentioned indicate the order of the shell, i.e., K, L, M, N,….respectively.

(v) Thus, the electronic configuration of hydrogen is written as 1, that of helium as 2, and that of lithium as 2, 1.

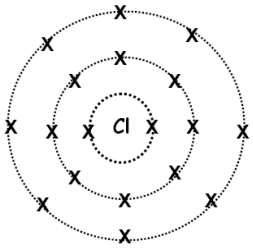
Table showing the Electronic configuration of first 20elements.
Distribution of electrons in various orbits is given in the following table.

Element	Symbol	K – shell	L – shell	M – shell	N – shell
Hydrogen	$_1$H	1			
Helium	$_2$He	2			
Lithium	$_3$Li	2	1		
Beryllium	$_4$Be	2	2		
Boron	$_5$B	2	3		
Carbon	$_6$C	2	4		
Nitrogen	$_7$N	2	5		
Oxygen	$_8$O	2	6		
Fluorine	$_9$F	2	7		
Neon	$_{10}$Ne	2	8		
Sodium	$_{11}$Na	2	8	1	
Magnesium	$_{12}$Mg	2	8	2	
Aluminium	$_{13}$Al	2	8	3	
Silicon	$_{14}$Si	2	8	4	
Phosphorous	$_{15}$P	2	8	5	
Sulphur	$_{16}$S	2	8	6	
Chlorine	$_{17}$Cl	2	8	7	
Argon	$_{18}$Ar	2	8	8	
Potassium	$_{19}$K	2	8	8	1
Calcium	$_{20}$Ca	2	8	8	2

Structures of atoms of some elements can be now represented as shown below



Oxygen atom



Argon atom

Valence shell

The last shell of an atom is called **ultimate shell** or **valence shell** and is represented by the symbol ‘ n’ . For example in sodium, the valence shell is M–shell.

Valence electrons

Electron(s) that are present in the valence shell are called **valence electrons.**

Core electrons

Electrons are present in shells except valence shell are called **core electrons.**

Ions

Ions are formed when an atom loses or gains one electron or more electrons. Ions are of two types :

(i) Cation: A cation is formed when an atom loses an electron or more electrons.

For example $A \xrightarrow{-e^-} A^{1+}$ (unipositive ion)

$A \xrightarrow{-2e^-} A^{2+}$ (bipositive ion)

Cations are positively charged ions.

(ii) Anion: An anion is formed when an atom gains an electron or more electrons.

For example

$A \xrightarrow{+e^-} A^-$ (uninegative ion)

$A \xrightarrow{-2e^-} A^{-2}$ (binegative ion)

Anions are negatively charged ions.

Isoelectronic species

Atoms or ions having same number of electrons are called **isoelectronic species.** Examples are

(i) Mg^{2+} and Al^{3+}

(ii) F^- and O^{2-}

1.
