CHAPTER 4

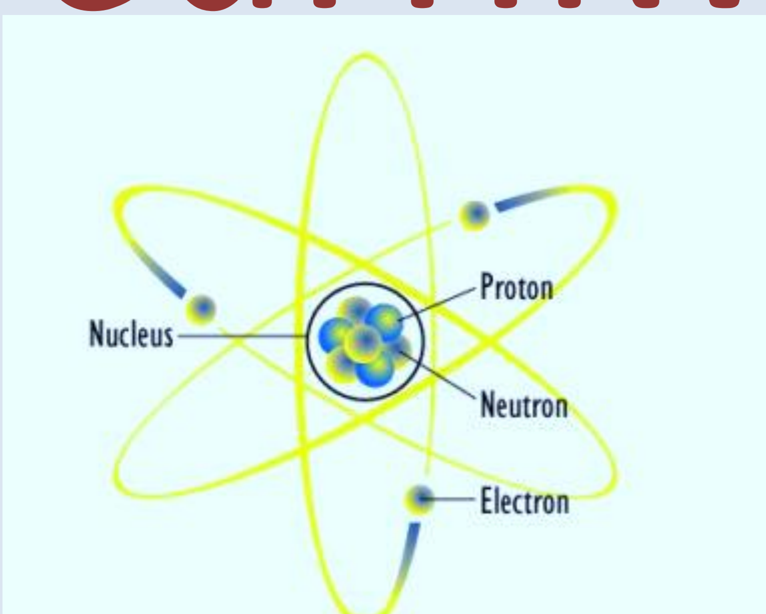
STRUCTURE OF ATOMS

Atom is the smallest unit of matter that is composed of a *positively charged centre termed as "<u>nucleus</u>"* and the central nucleus is *surrounded by negatively charged electrons*. Even though an atom is the smallest unit of matter but it retains all <u>the chemical properties of an element</u>. For example, a silver spoon is made up of silver atoms with few other constituents. A silver atom obtains its properties from tiny subatomic particles that it is composed of.

Atoms are further arranged and organized to form larger structures known as molecules.

Structure of an atom can be basically divided into two parts:

- **an atomic nucleus**
- **extra nucleus part**



- **The tiny atomic nucleus is the centre of an atom constituting positively charged particles "protons" and uncharged particles "**neutrons**."**
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Thomson's atomic model

- **J. J. Thomson, who discovered the electron in 1897, proposed the plum pudding model of the atom in 1904 before the discovery of the atomic nucleus in order to include the electron in the atomic model. In Thomson's model, the atom is composed of electrons (which Thomson still called "corpuscles,"**
- **According to the postulates of Thomson's atomic model, an atom resembles a sphere of positive charge with electrons (negatively charged particles) present inside the sphere. The positive and negative charge is equal in magnitude and therefore an atom has no charge as a whole and is electrically neutral**
- **Thomson's atomic model failed to explain how the positive charge holds on the electrons inside the atom. It also failed to explain an atom's stability. The theory did not mention anything about the nucleus of an atom.**

RUTHERFORD'S MODEL OF AN ATOM

- **Rutherford designed an experiment for this. In this experiment, fast moving alpha α particles were made to fall on a thin gold foil.**
- **He selected a gold foil because he wanted as thin a layer as possible. This gold foil was about 1000 atoms thick.**
- **α-particles are doubly-charged helium ions. Since they have a mass of 4 u, the fast-moving α-particles have a**
- **considerable amount of energy.**
- **It was expected that α-particles would be deflected by the sub-atomic particles in the gold atoms. Since the α-particles were much heavier than the protons, he did not expect to see large deflections. following observations were made:**
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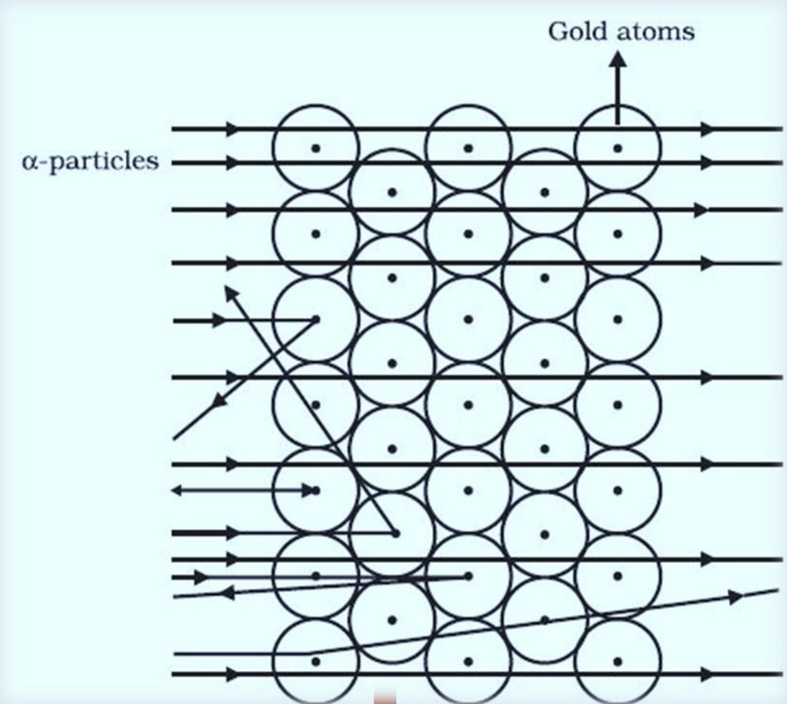
- **(i) Most of the fast-moving α-particles passed straight through the gold foil.**
- **(ii) Some of the α-particles were deflected by the foil by small angles.**
- **(iii) Surprisingly one out of every 12000 particles appeared to rebound**



Rutherford
concluded from the □-particle scattering experiment that–

(i) Most of the space inside the atom is empty because most of the □-particles passed through the gold foil without getting deflected.
(ii) Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.
(iii) A very small fraction of □-particles were deflected by 1800, indicating that all the positive charge and mass of the
the
On the basis of his experiment, Rutherford put forward the nuclear model of an atom, which had the following features:

(i) There is a positively charged centre in an atom called the nucleus. Nearly all the mass of an atom resides in the nucleus.
(ii) The electrons revolve around the nucleus in well-defined orbits.

- **(iii) The size of the nucleus is very small as compared to the size of the atom.**
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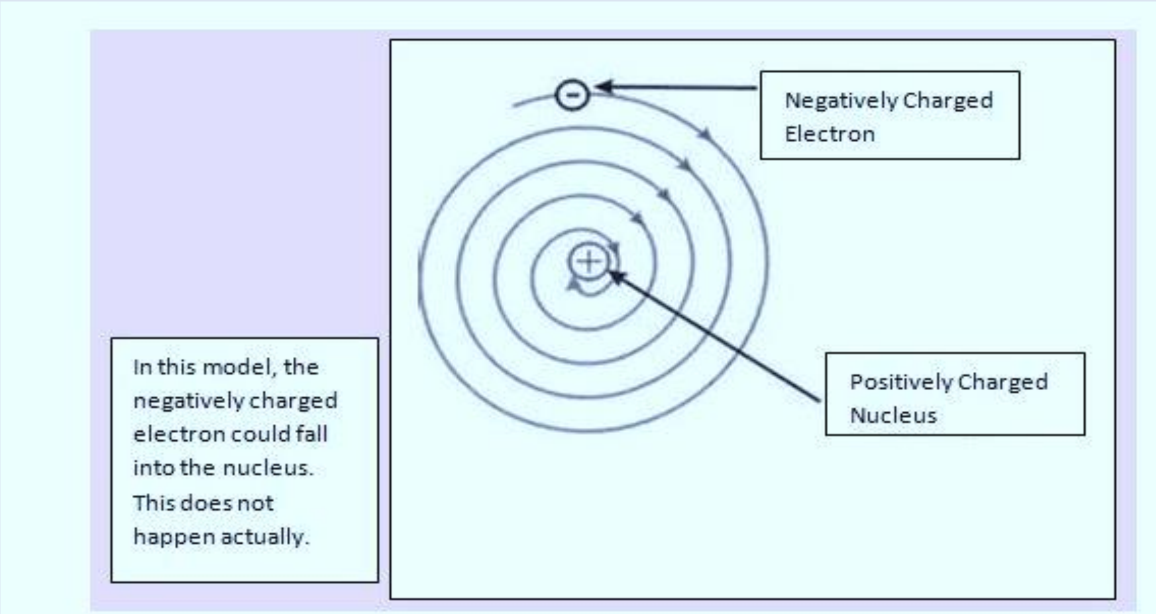
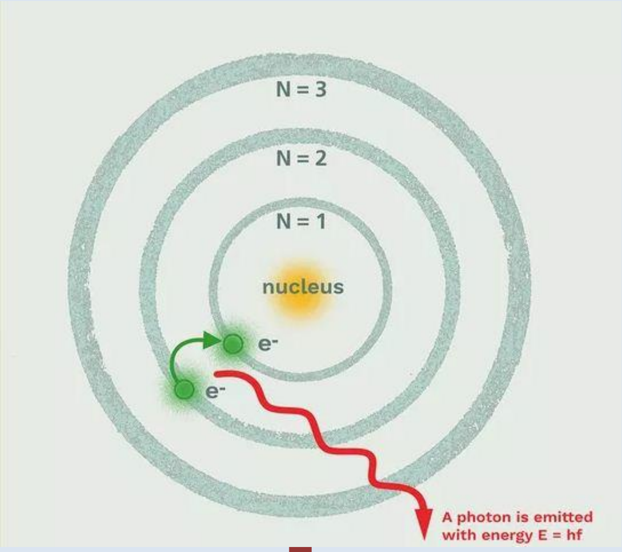
Drawbacks of Rutherford's model of the atom

- **Rutherford proposed that electrons revolve at a high speed in circular orbits around the positively charged nucleus. When a charged particle i. e. electron revolves around positively charge nucleus, it needs to be accelerated so as to keep it moving in circular orbits. However, according to electromagnetic theory, whenever a charged particle such as an electron is accelerated around another charged center (nucleus) which are under force of attraction, there will be continuous radiation of energy. This loss of energy would slow down the speed of the electron. This would reduce the radius of the electron–orbit. Eventually the electron would fall into the nucleus. The result would be that the atom would collapse. But this does not happen. Thus Rutherford's atom could not explain the stability of the atom. Failure of Rutherford's model i.e. reduction of radius of orbit is shown below.**
- **Rutherford proposed that electrons revolve around the nucleus in the fixed orbits. However, he did not specify the orbits and the number of electrons in each orbit.**



BOHR'S MODEL OF ATOM

- **The Bohr Model has an atom consisting of a small, positively charged nucleus orbited by negatively charged electrons.**
- **The Bohr Model is a planetary model in which the negatively charged electrons orbit a small, positively charged nucleus similar to the planets orbiting the sun (except that the orbits are not planar). The gravitational force of the solar system is mathematically akin to the Coulomb (electrical) force between the positively charged nucleus and the negatively charged electrons.**



Main Points of the Bohr Model

- **Electrons orbit the nucleus in orbits that have a set size and energy.**
- **The energy of the orbit is related to its size. The lowest energy is found in the smallest orbit.**

Radiation is absorbed or emitted when an electron moves from one orbit to another

Neutrons

- **Neutrons are the largest of the particles that make up the atom. Neutrons are found in the nucleus of the atom. They are tightly packed with the protons. The** protons and neutrons are held together in the nucleus with a force called the strong nuclear force. The nucleus is a very dense area that is found in the center of the atom.

- **Neutrons have a neutral charge or actually no charge at all. Its partner in the nucleus, the proton, does have a positive charge. The proton's positive charge is matched with the electron's negative charge to make a neutral atom.**

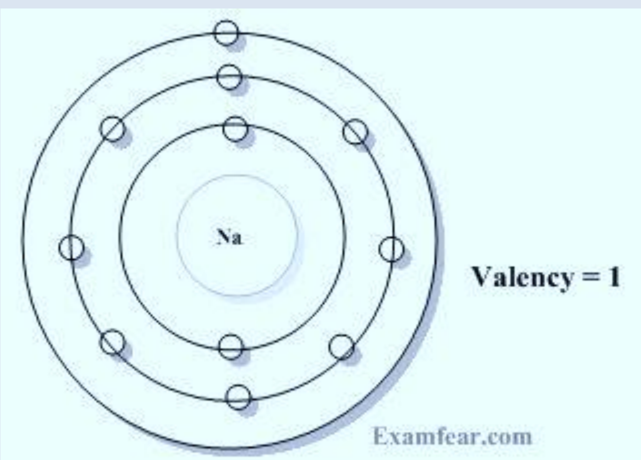
How are Electrons Distributed in Different Orbits (Shells)?

- **The distribution of electrons into different orbits of an atom was suggested by Bohr and Bury.**
- **The following rules are followed for writing the number of electrons in different energy levels or shells:**
- **(i) The maximum number of electrons present in a shell is given by the formula 2n2, where 'n' is the orbit**
- **number or energy level index, 1,2,3,…. Hence the maximum number of electrons in different shells are as**
- **follows:**
- **first orbit or K-shell will be = 2 □□ 12 = 2,**
- **second orbit or L-shell will be = 2 □□ 22 = 8,**

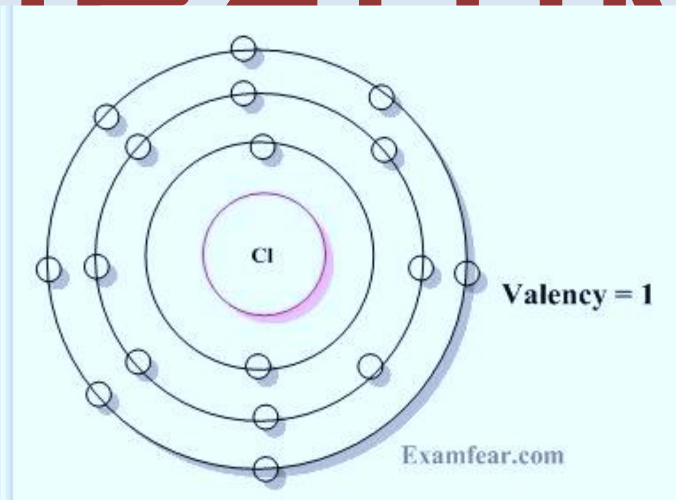
- third orbit or M-shell will be = 2 □ 32 = 18,
- fourth orbit or N-shell will be= 2 □□ 42= 32, and so on.
- (ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.
- (iii) Electrons are not accommodated in a given shell, unless the inner shells are filled. That is, the shells are filled in a step-wise manner.

Valency

- It is the ability of an atom to gain or lose electron in order to achieve the noble gas configuration. It refers to the ability of an element to combine with other element. It is obtained by determining the number of electrons in the outermost shell (also called valence shell) of each atom of an element. For instance, sodium has 1 electron in its outermost shell and hence valency of sodium is 1.



- Atomic number of sodium is 11. So the electronic configuration stands out to be 2,8,1 i.e. there is one electron in the outermost shell. In order to gain inert gas configuration it is better for sodium to lose one electron and achieve the nearest noble gas configuration of neon with atomic number 10.
- On the other hand atomic number of chlorine is 17. So electronic configuration stands out to be 2,8,7. In order to achieve noble gas configuration to become stable it requires one electron then it will acquire the configuration of neon (noble gas). Therefore valency of chlorine is1.



- That means the every element tries attain stability by acquiring noble gas configuration for which it tries to either gain electron or donate electron. Na donates 1 electron in its outermost shell to attain noble gas configuration whereas chlorine acquires 1 electron in its outermost shell to acquire noble gas configuration.

- Metals are electropositive because they have tendency to lose electrons. E.g. Na+ whereas non-metals are electronegative since they have a tendency to gain electrons. E.g. Cl-.
- We can find the valency of an element through its atomic number and its electronic configuration. For instance,
- In Boron with atomic number 5, the configuration stands out to be 2,3 and it has 3 electrons in its outermost shell. Being a metal Boron has a tendency to lose its electrons to gain noble gas configuration and shows its valency 3.
- Whereas in Fluorine with atomic number 9, the configuration stands out to be 2,7 and it has 7 electrons in its valence shell and needs to gain 1 more electron to achieve noble gas configuration and hence its valency is 1.

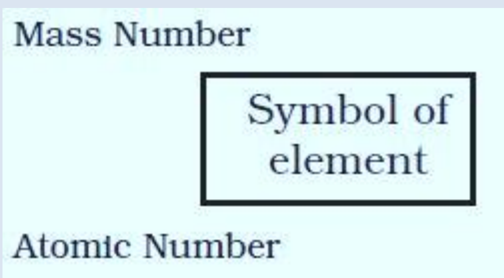
Atomic Number and Mass Number

Atomic Number

- The atomic number (represented by the letter Z) of an element is the number of protons in the nucleus of each atom of that element. An atom can be classified as a particular element based solely on its atomic number. For example, any atom with an atomic number of 8 (its nucleus contains 8 protons) is an oxygen atom, and any atom with a different number of protons would be a different element.

<u>**Mass Number**</u>

- **The mass number is defined as the sum of the total number of protons and neutrons present in the nucleus of an atom.**
- **In the notation for an atom, the atomic number, mass number and symbol of the element are to be written as:**
- **For example**



For example, nitrogen is written as ${}^{14}_{7}\mathrm{N}$.

- **the properties of the subatomic particles of an atom, we can conclude that mass of an atom is practically due to**

- **protons and neutrons alone. These are present in the nucleus of an atom. Hence protons and neutrons are also called nucleons. Therefore, the mass of an atom resides in its nucleus. For example, mass of carbon is 12 u because it has 6 protons and 6 neutrons, 6 u + 6 u = 12 u. Similarly, the mass of aluminium is 27 u (13 protons+14 neutrons).**

Isotopes

- Isotopes are defined as the atoms of the same element, having the same atomic number but different
- mass numbers.
- An isotope of a chemical element is an atom that has a different number of neutrons (that is, a greater or lesser atomic mass) than the standard for that element. The atomic number is the number of protons in an atom's nucleus.
- Carbon 12 and Carbon 14 are both isotopes of carbon, one with 6 neutrons and one with 8 neutrons (both with 6 protons). Carbon-12 is a stable isotope, while carbon-14 is a radioactive isotope (radioisotope). Uranium-235 and uranium-238 occur naturally in the Earth's crust

- There are two main types of isotopes, and these are radioactive isotopes and stable isotopes.
- Stable isotopes have a stable combination of protons and neutrons, so they have stable nuclei and do not undergo decay. These isotopes do not pose dangerous effects to living things, like radioactive isotopes
- Radioactive isotope, also called radioisotope, radionuclide, or radioactive nuclide, any of several species of the same chemical element with different masses whose nuclei are unstable and dissipate excess

energy by spontaneously emitting radiation in the form of alpha, beta, and gamma rays.

- **Stable isotopes are elements with the same number of protons but different number of neutrons. Carbon exists as two stable isotopes: 12C, which has six electrons, six protons, and six neutrons, and 13C, which has six electrons, six protons, and seven neutrons.**
- **Since the chemical properties of all the isotopes of an element are the same, normally we are not concerned about taking a mixture. But some isotopes have special properties which find them useful in various fields. Some of them are :**
- **(i) An isotope of uranium is used as a fuel in nuclear reactors.**
- **(ii) An isotope of cobalt is used in the treatment of cancer.**
- **(iii) An isotope of iodine is used in the treatment of goitre**
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ISOBARS

- **Atoms of chemical elements having same atomic mass but a different atomic number are called Isobars. The sum of the number of protons and neutrons together form the atomic mass. the number of nucleons present in the nucleus is equal to the atomic mass of an atom. It will have the same number of nucleons.**
- **The number of protons and neutrons alone will vary but the number of nucleons or the sum of protons and neutrons in isobars will always be same. Isobars always have different atomic structure because of the difference in atomic numbers. The number of neutrons makes up the difference in the number of nucleons. Therefore, they are always different chemical elements having same atomic masses. Thus, isobar has different chemical properties.**