SHORT NOTES: CLASS 9
CHAPTER 4: STRUCTURE OF THE ATOM

DISCOVERY AND DISCOVERER:

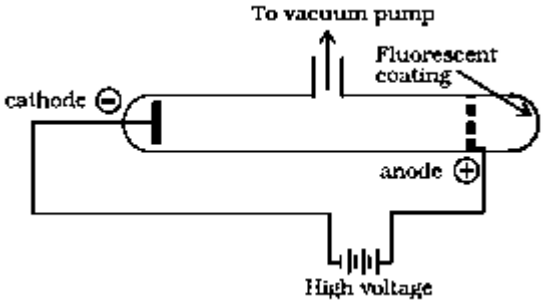
- **Electron** — J.J. Thomson
- **Proton** — E. Goldstein
- **Neutron** — J. Chadwick
- **Nucleus** — Rutherford

Cathode Rays: Discovery of Electron:

In 1897, Sir Joseph John Thomson performed a cathode ray discharge tube experiment which led to the discovery of electrons. http://www.physicsinduction.com

Cathode ray discharge tube experiment: A discharge tube is a long glass tube having two metal rods connected to the oppositely charged poles of a battery. A gas is filled in it, at low pressure. The pressure of the gas inside the discharge tube is controlled by a vacuum pump connected to the tube.

When pressure is reduced to about 10^{-2} atmosphere and high voltage (of about 10000 V d.c.) is applied between the two electrodes, a bright spot of light is formed on the zinc sulphide screen kept at the opposite end of the cathode. http://www.physicsinduction.com



This was caused by the rays that originated from the cathode hence called cathode rays.

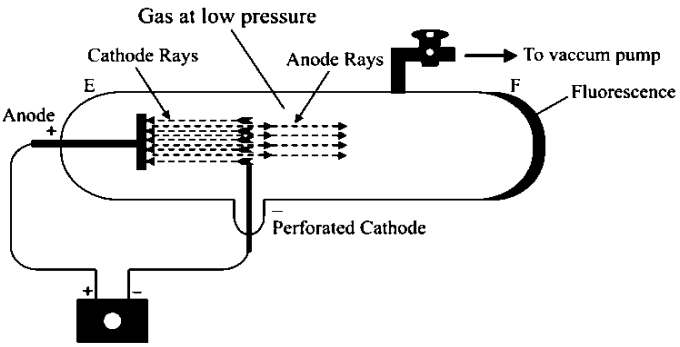
Electrons: The negatively charged particles constituting the cathode rays are called electrons.

Charge on an electron = -1.6×10^{-19} C

Mass = 9.109×10^{-31} Kg= 9.1×10^{-28} g (nearly $1/1837^{th}$ of that of hydrogen atom)

Anode Rays: Discovery of Proton:

Eugen Goldstein in 1886 performed a discharge tube experiment with a porous or perforated cathode and it was placed somewhere in the centre of the tube and not at the end. Hydrogen gas was enclosed in the discharge tube. He also observed fluorescence behind the perforated cathode. These rays were coming from the side of the anode in straight lines opposite to that of cathode rays. These rays were originally called **'canal rays'** as they passed through the perforated cathode.



These rays were called **positive rays by J.J. Thomson.** They were named **anode rays** as they were directed away from the anode.

The smallest and lightest positive ion was obtained from hydrogen and was named as proton by Rutherford. http://www.physicsinduction.com

Protons: The positively charged particles are called protons.

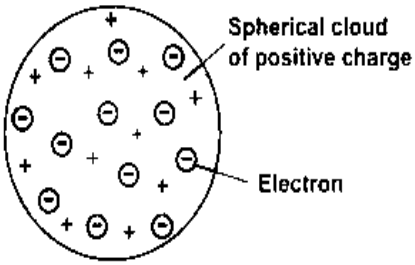
Charge on a Proton = 1.6×10^{-19} C Mass = 1.6×10^{-27} Kg= 1.6×10^{-24} g

ATOMIC MODELS

1. **THOMSON'S MODEL OF AN ATOM:** According to J.J. Thomson-

(a) An atom contains negatively charged particles called electrons embedded uniformly throughout a thinly spread positively charged spherical mass. http://www.physicsinduction.com

(b) Since the atom is electrically neutral, the total negative charge of electrons is balanced by the total positive charge. i.e., in an atom, the total number of electrons is equal to the total number of protons



This model is popularly known as a **plum-pudding model** or **apple-pie model** or **watermelon model.** This model can be visualized as a pudding or watermelon of positive charge with plums or seeds (electrons) embedded into it. http://www.physicsinduction.com

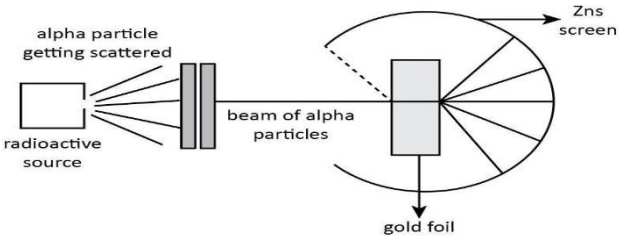
Note: An important feature of this model is that the mass of the atom is assumed to be uniformly distributed over the atom.

Limitations: Although, this model was able to explain the overall neutrality of the atom, it was not consistent with the results of later experiments conducted by other scientists.

2. **RUTHERFORD'S MODEL OF AN ATOM: α-ray scattering experiment**

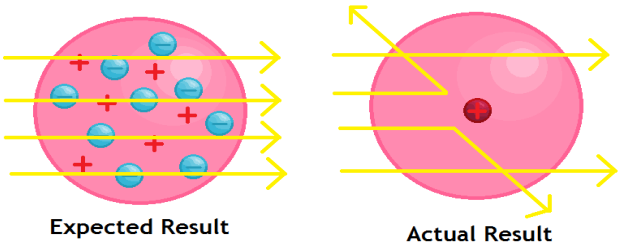
Ernst Rutherford's gold foil experiment is also known as the Geiger-Marsden experiment. In this experiment, fast-moving α-particles were made to fall on a thin gold foil. http://www.physicsinduction.com

Why Gold foil? Gold is quite malleable and he wanted as thin a layer as possible. This gold foil was about 1000 atoms thick.



Why α-particles? α-particles are doubly charged He ions. Since they have a mass of 4 u, the fast-moving α-particles have a considerable amount of energy.

Expectations: 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. http://www.physicsinduction.com



Observations:

(a) Most of the α-particles passed through the gold foil undeflected.
(b) Some of the α-particles were deflected by small angles.
(c) Very few α-particles deflected back. One out of every 12000 α-particles appeared to rebound.
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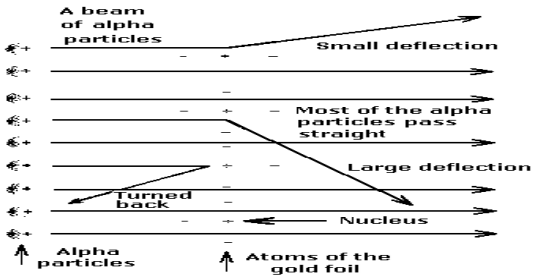
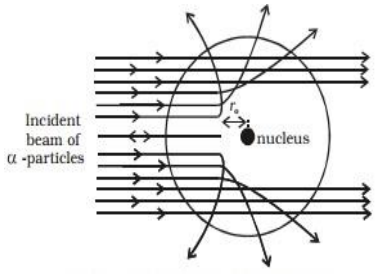




Conclusions: http://www.physicsinduction.com

(a) Since most of the α-particles passed undeflected, so majority of space inside the atom is empty.

(b) Since very few particles are deflected, hence the positive charge of an atom occupies very little space.

(c) A very small fraction of α-particles was deflected by 180° (complete deflection), indicating that positive charge is concentrated in a very small volume called the nucleus.

On the basis of his experiments, Rutherford proposed an **atomic model**, according to which an atom consists of two distinct parts:

(a) Nucleus (b) Extra-nuclear part

(a) The Nucleus-Centre of an atom:

(i) There is a positively charged centre in an atom called the nucleus.

(ii) The entire mass of an atom resides in the nucleus.

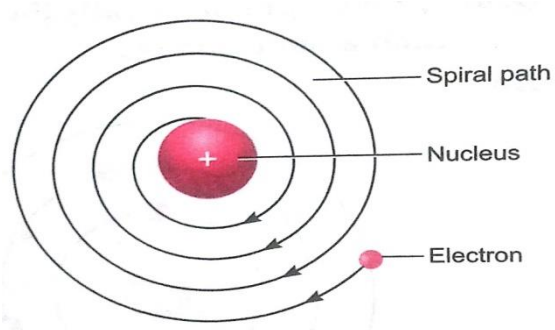
(iii) The radius of the nucleus is about 10^5 less than the radius of the atom.

(b) Extra-nuclear part: http://www.physicsinduction.com

(i) Since an atom is electrically neutral, the total number of protons in the nucleus is equal to the total number of electrons present outside the nucleus.

(ii) Negatively charged electrons revolve around the nucleus at a very high speed and are attracted by electrostatic force from the nucleus. This attraction is counterbalanced by an outward centrifugal force keeping the electron in its orbit.

Limitations of Rutherford's atomic model: He could not explain the stability of an atom. According to Maxwell's electromagnetic theory, if any charged particle (electron) shows acceleration in the electric and magnetic field of another charged body (proton), it loses energy and the radius also decreases, its path becomes spiral and finally, it falls into the nucleus and hence the atom should be unstable.



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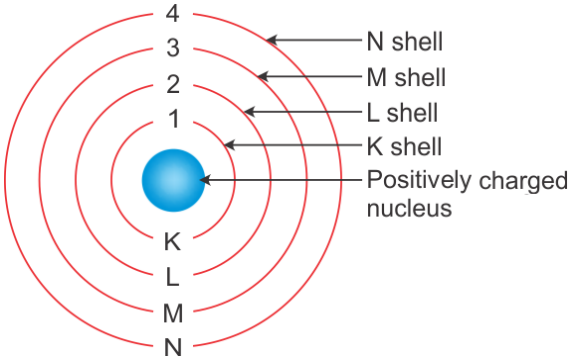
3. BOHR'S MODEL OF AN ATOM: In order to overcome the limitations of Rutherford's atomic model, Neils Bohr put forward the following postulates:

(a) The electrons always move in certain stationa orbits known as discrete orbits which have fix energies. These orbits are also called shells or energy levels. These energy levels are http://www.physicsinduction.comrepresented by the letters K, L, M, N shells or numbers, n=1,2,3,4... etc. The energy level near the nucleus is called a lower energy level and as the distance from the nucleus increases, we proceed from lower to higher energy level.



(b) In a particular energy level, an electron neither loses nor gains energy.

(i) The gain or loss of energy takes place only when an electron changes its energy level/orbit.

(ii) When it jumps from lower to higher energy levels, it absorbs energy. This time electron is said to be in an excited state. http://www.physicsinduction.com

(iii) Because the excited state provides instability to the electron, as soon as possible, electron tends to come back to its ground state to gain stability. This time electron emits energy equal to that of absorbed energy.

The success of Bohr's Model:

(a) **Stability of atom:** Bohr's model shows that an electron does not lose its energy as long as it revolves in a particular orbit and hence it can not fall into the nucleus by losing energy.

(b) It introduced the idea of quantized energy states of an electron in an atom.

Limitations of Bohr's Model: Bohr's model is applicable to a single electron system i.e., only applicable to hydrogen or hydrogen-like species (containing only one electron like He^{+}, Li^{2+}, $Be^{3+,}$ etc.) and fails for a multielectron system. http://www.physicsinduction.com

DISCOVERY OF NEUTRON: Neutrons were discovered by **James Chadwick** in 1932.

Properties of neutrons:

(a) Neutrons are electrically neutral.

(b) Except protium($_{1}^{1}H$), all atoms have neutrons. **Protium is also called as ordinary hydrogen.**

(c) Variation in atomic masses of isotopes shows the existence of neutrons.
Mass: 1.6×10^{-27} Kg= 1.6×10^{-24} g; Charge = zero

Note:

(a) Protons and neutrons together are called **'Nucleons'.** http://www.physicsinduction.com

(b) Due to its neutral nature, neutrons can penetrate the nuclei and are responsible for nuclear reactions.

ELECTRONIC CONFIGURATION OF AN ELEMENT

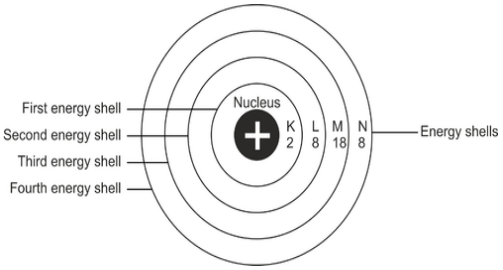
Arrangement of electrons in an atom: Bohr-bury Scheme:

The Bohr and Bury scheme gives the following rules for the distribution of electrons in various orbits.

(a) The maximum number of electrons present in a shell is given by the formula $2n^2$, where n is the orbit number or energy level index. For example, for K shell: n=1 ∴ maximum number of electrons $=2(1)^2=2$

(b) The maximum number of electrons that can be accommodated in the outermost orbit is 8.

(c) Inner shells or lower energy levels will be filled first. When inner shells are filled completely then only outer shells will be filled. http://www.physicsinduction.com



Electronic Configuration: The distribution or arrangement of the electrons in the different shells of the atom is called the electronic configuration of the element.

Example: Carbon, C: Total number of electrons = 6

The shell corresponding to n =1(K-shell) will have 2 electrons and corresponding to n =2 (L-shell) will have 4 electrons. So, the Electronic Configuration of carbon = 2,4

VALENCY AND VALENCE ELECTRONS http://www.physicsinduction.com

Valence Electrons: The electrons present in the outermost shell of the atom of an element are called valence electrons. The outermost shell is called the valence shell.

Valency: Valency is the combining capacity of an atom.

Octet Rule: To attain stability, atoms lose, gain, or share electron(s) with other atoms so as to complete their octet. http://www.physicsinduction.com

The number of electrons shared or transferred to complete the octet is termed as **valency** of the atom.

(a) If electrons are transferred (lost or gained), it is termed as **electrovalency.**

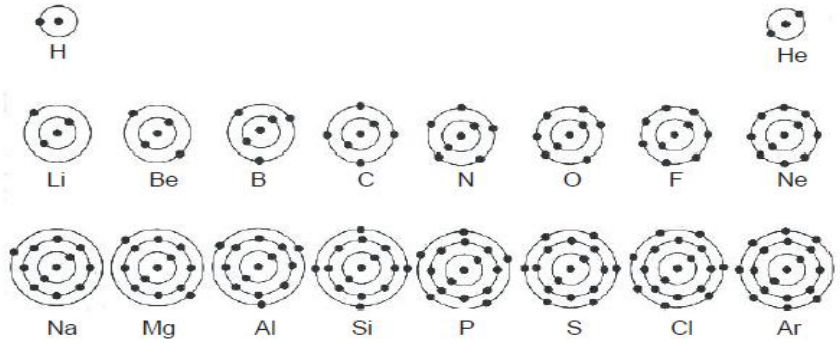
(b) If electrons are shared, it is termed as **covalency.**

Calculation of Valency:

(a) For elements having valence electrons, 1,2 or 3, valency is equal to the number of valence electrons.

(b) For elements having valence electrons, 4,5,6 or 7, valency is equal to (8-number of valence electrons).

Electronic distribution:



ATOMIC NUMBER AND MASS NUMBER

Atomic Number(Z): The atomic number of an atom is determined by the number of protons present in the atom. It is denoted by 'Z'. http://www.physicsinduction.com

$$Z = p$$

Mass number(A): Mass number is defined as the sum of the total number of protons and neutrons present in the nucleus of an atom. It is denoted by 'A'.

$$A = n + p$$

Notation of an Atom: ${}^{A}_{Z}X$, where X is the symbol of the element.

ISOTOPES AND ISOBARS http://www.physicsinduction.com

Isotopes:

(a) Isotopes are the atoms of the same element that have the same atomic number (number of protons) but different mass numbers.

(b) An atom of a given element may have a wide range in its number of neutrons. Isotopes exist due to different numbers of neutrons present in the atoms of the same element.

(c) The chemical properties of isotopes are similar but their physical properties are different.

Examples: http://www.physicsinduction.com

(a) Isotopes of hydrogen: $^{1}_{1}$H(Protium); $^{2}_{1}$H or D(Deuterium); $^{3}_{1}$H or T(Tritium)

(b) Isotopes of Lithium: $^{6}_{3}$Li, $^{7}_{3}$Li, $^{8}_{3}$Li

(c) Isotopes of Carbon: $^{12}_{6}$C, $^{13}_{6}$C, $^{14}_{6}$C

$^{14}_{6}$C is a radioactive isotope of carbon used for determining the age of fossils. The technique used is known as 'Carbon Dating'.

(d) Isotopes of Chlorine: $^{35}_{17}$Cl, $^{37}_{17}$Cl http://www.physicsinduction.com

Average atomic mass of Isotopes: Isotopes are found in nature in some particular ratio and on this basis average atomic mass of an isotope can be calculated.

Example: The average atomic mass of Chlorine is 35.5u: The two isotopes of chlorine $^{35}_{17}$Cl and $^{37}_{17}$Cl are present in nature in the ratio 3:1 respectively.

∴The average atomic mass of chlorine = $\frac{(35\times3)+(37\times1)}{4}$ = 35.5u

Applications of isotopes:

(a) An isotope of uranium (U-235) is used as fuel in nuclear reactors.

(b) An isotope of cobalt (Co-60) is used in the treatment of cancer.

(c) An isotope of iodine (I-131) is used in the treatment of goitre.

(d) An isotope of phosphorus(P-32) is used in the treatment of leukaemia.

(e) Arsenic-74 is employed to detect tumors. http://www.physicsinduction.com

(f) Blood clots in the circulatory system are located by sodium-24.

Isobars: Isobars are the atoms of different elements that have different atomic numbers but the same mass numbers, i.e., they have different numbers of protons(p) but the same number of nucleons (n+p).

Example: Argon, $^{40}_{18}$Ar and Calcium, $^{40}_{20}$Ca are isobars of each other.

Isotones: Isotones are atomic species that share the same number of neutrons and differ in the number of protons.

Example: $^{14}_{6}$C, $^{15}_{7}$N and $^{16}_{8}$O are isotones of each other. http://www.physicsinduction.com

Element	p	n + p	n = (n + p)-p
$^{14}_{6}$C	6	14	n= 14-6 = 8
$^{15}_{7}$N	7	15	n= 15-7 = 8
$^{16}_{8}$O	8	16	n= 16-8 =8

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CONTACT DETAILS: all.about.physics1485@gmail.com, 8168258349