Greenwood Public School

Chapter 4

Structure Of The Atom

Class 9

Essentially, the structure of an atom comprises of protons, neutrons and electrons. These basic components provide the mass and charge of the atoms. The nucleus comprises of proton and neutron, with the electron orbiting around that.

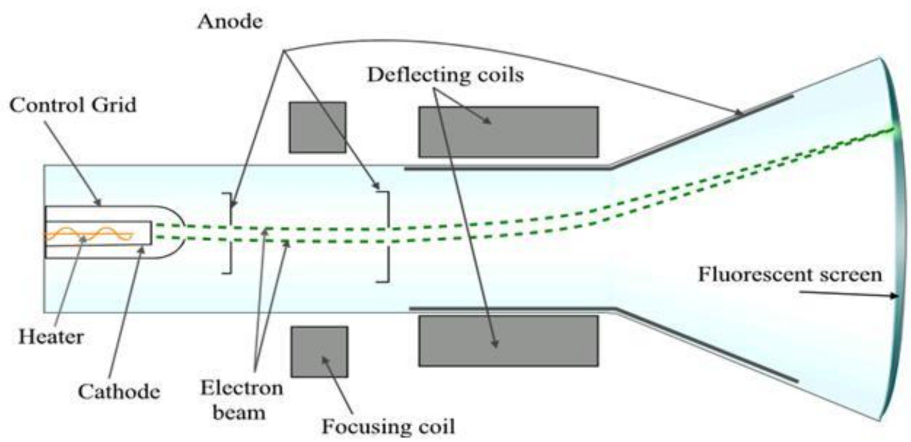
Introduction to Structure of an Atom

Atoms

Atoms are the building blocks of matter. It is the smallest unit of matter that is composed of three sub-atomic particles: the proton, the neutron, and the electron.

Cathode ray experiment

- J. J. Thomson discovered the existence of electrons.
- He did this using a **cathode ray** tube, which is a vacuum-sealed tube with a **cathode** and anode on one end that created a beam of electrons travelling towards the other end of the tube.
- The air inside the chamber is subjected to high voltage and electricity flows through the air from the negative electrode to the positive electrode.
- The characteristics of cathode rays (electrons) do not depend upon the material of electrodes and the nature of the gas present in the cathode ray tube.
- The experiment showed that the atom was not a simple, indivisible particle and contained at least one subatomic particle – the electron.



Apparatus of the experiment

Electrons

- Electrons are the negatively charged sub-atomic particles of an atom.
- The mass of an electron is considered to be negligible, and its charge is -1.
- The symbol for an electron is e^-
- Electrons are extremely small.
- They are found outside the nucleus.

Thomson's model of an atom

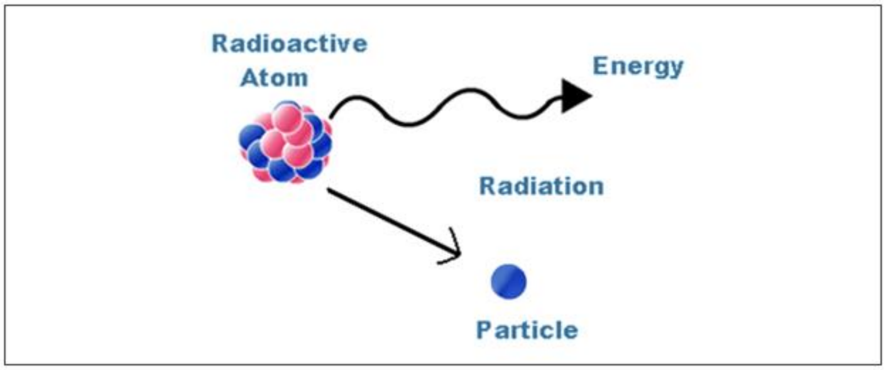
- According to Thomson,(i) An atom consists of a positively charged sphere, and the electrons are embedded in it. (ii) The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral
- The first model of an atom to be put forward and taken into consideration.
- He proposed a model of the atom be similar to that of a Christmas pudding/watermelon.
- The red edible part of the watermelon is compared with the positive charge in the atom.
- The black seeds in the watermelon are compared with the electrons which are embedded on it.

Radioactivity

Radioactivity

- Radioactivity is the term for the process by which an unstable nucleus of an atom loses energy by giving out particles.

- It does so by giving out particles such as alpha and beta particles.
- This process is spontaneous.
- An atom is unstable if the nucleus has an imbalance, meaning a difference in the protons and neutrons.



Rutherford Model

Rutherford's experiment and observations

In this experiment, fast-moving alpha (α)-particles were made to fall on a thin gold foil. His observations were:

- A major fraction of the α-particles bombarded towards the gold sheet passed through it without any deflection, and hence **most of the space in an atom is empty**.
- Some of the α-particles were deflected by the gold sheet by very small angles, and hence the **positive charge** in an atom **is not uniformly distributed**.
- **The positive charge** in an atom **is concentrated in a very small volume**.
- Very few of the α-particles were deflected back, that is only a few α-particles had nearly 180o angle of deflection. So the **volume occupied by the positively charged particles in an atom is very small as compared to the total volume of an atom**.

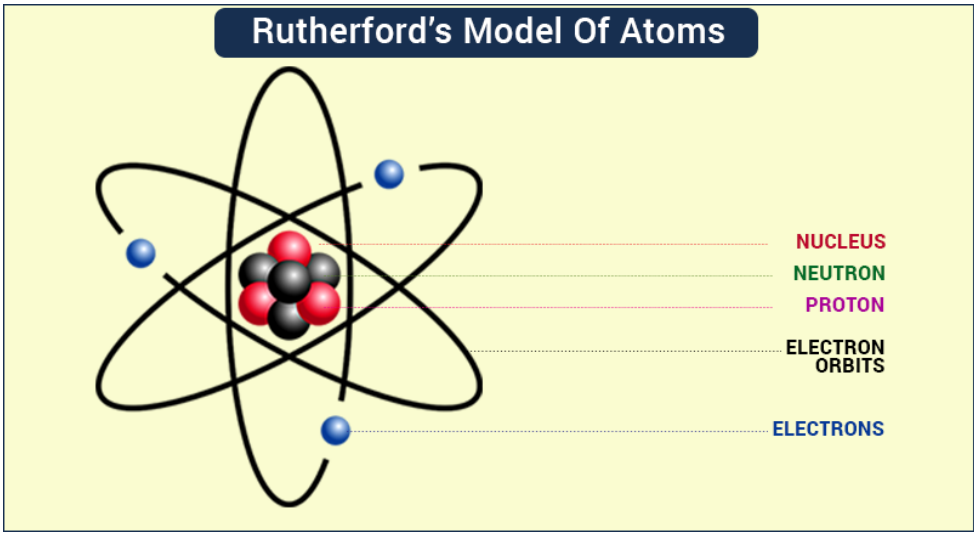
Rutherford's model of an atom

Rutherford concluded the model of the atom from the α-particle scattering experiment as:

(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.



Rutherford's Model

Drawbacks of Rutherford's model

- He explained that the electrons in an atom revolve around the nucleus in well-defined orbits. Particles in a circular orbit would experience acceleration.
- Thus, the revolving electron would lose energy and finally fall into the nucleus.
- But this cannot take place as the atom would be unstable and matter would not exist in the form we know.

Be More Curious!!!

- The Millikan's Oil Drop Experiment was an experiment performed by Robert A. Millikan and Harvey Fletcher in 1909 to measure the charge of an electron.
- In the experiment, Millikan allowed charged tiny oil droplets to pass through a hole into an electric field.
- By varying the strength of electric field, the charge over an oil droplet was calculated, which always came as an integral value of **'e.'**
- The conclusion of this is that the charge is said to be quantized, i.e. the charge on any particle will always be an integral multiple of e which is $1.6*10^{-19}$

Neil Bohr Model

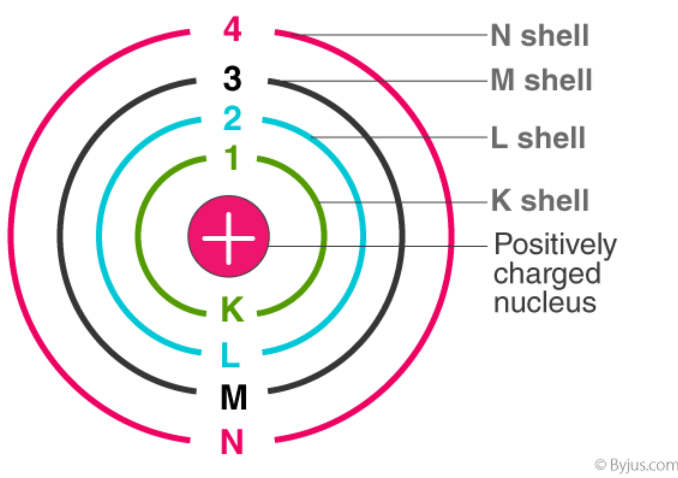
Properties of electrons, protons, and neutrons

Particle	*Charge on the particle*	*Mass of the particle*	*Symbol*	*Location in the atom*
1. *Electron*	-1 *unit* $(-1.602 \times 10^{-19}$ *coulomb*$)$	9.11×10^{-31} *kg* $\left(\frac{1}{1840}u\right)$	${}^{0}_{-1}e$	*Outside the nucleus (Extranuclear part)*
2. *Proton*	$+1$ *unit* $(+1.602 \times 10^{-19}$ *coulomb*$)$	1.673×10^{-27} *kg* $(1\ u)$	${}_{+1}p^{1}$	*In the nucleus*
3. *Neutron*	*No charge*	1.675×10^{-27} *kg* $(1\ u)$	${}^{1}_{0}n$	*In the nucleus*

Bohr’s Model of an atom

Bohr came up with these postulates to overcome the objections raised against Rutherford’s model:

- Electrons revolve around the nucleus in stable orbits without emission of radiant energy. Each orbit has a definite energy and is called an energy shell or energy level.
- An orbit or energy level is designated as K, L, M, N shells. When the electron is in the lowest energy level, it is said to be in the ground state.
- An electron emits or absorbs energy when it jumps from one orbit or energy level to another.
- When it jumps from a higher energy level to lower energy level, it emits energy while it absorbs energy when it jumps from lower energy level to higher energy level.



Orbits

Orbits are energy shells surrounding the nucleus in which electrons revolve.

Electron distribution in different orbits

The distribution was suggested by Bohr and Bury;

- 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, 1,2,3,….
- The maximum number of electrons in different shells are as follows: the first orbit will have $2*1^2=2$, the second orbit will have 2*2Msup>2=8, the third orbit will have $2*3^2=18$, fourth orbit $2*4^2=32$ and so on.
- The shells are always filled in a step-wise manner from the lower to higher energy levels. Electrons are not filled in the next shell unless previous shells are filled.

Valency

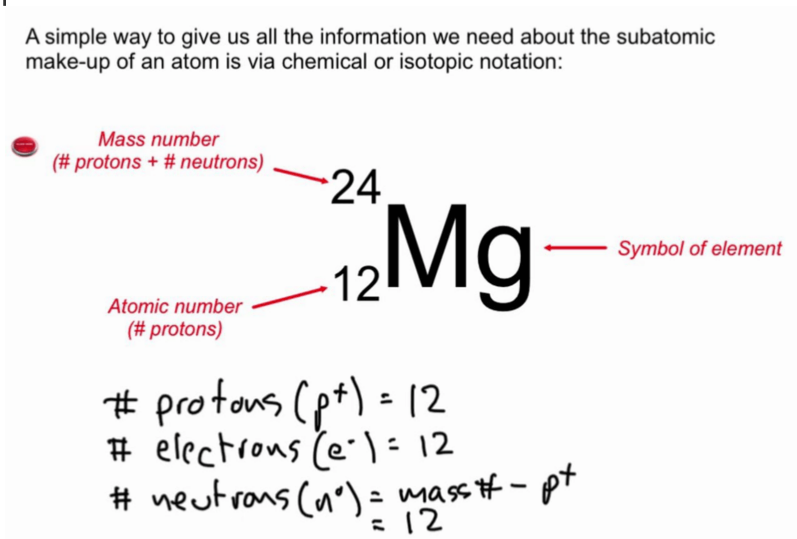
- The electrons present in the outermost shell of an atom are known as the valence electrons.
- The combining capacity of the atoms or their tendency to react and form molecules with atoms of the same or different elements is known as valency of the atom.
- Atoms of elements, having a completely filled outermost shell show little chemical activity.
- Their combining capacity or valency is zero.
- For example, we know that the number of electrons in the outermost shell of hydrogen is 1, and in magnesium, it is 2.
- Therefore the valency of hydrogen is 1 as it can easily lose 1 electron and become stable.
- On the other hand, that of magnesium is 2 as it can lose 2 electrons easily and also attain stability.

Atomic Number

The number of protons found in the nucleus of an atom is termed as the atomic number. It is denoted by the letter ‘Z’.

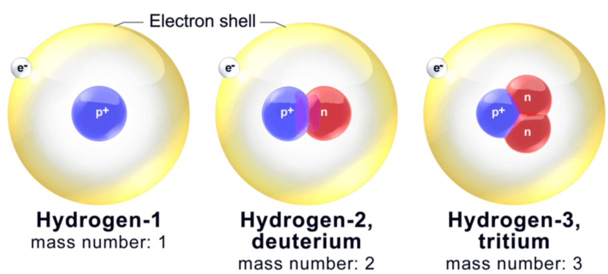
Mass number and representation of an atom

Protons and neutrons are present in the nucleus, so the mass number is the total of these protons and neutrons.



Isotopes and Isobars

Isotopes are defined as the atoms of the same element, having the same atomic number (number of protons) but different mass numbers (number of protons+neutrons).
For example: In the case of Hydrogen we have:



Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.
For example, Calcium and Argon: both have the same mass number – 40
$_{20}Ca^{40}$ and $_{18}Ar^{40}$

Calculation of mass number for isotopic elements

When an element has an isotope, the mass number can be calculated by the different proportions it exists in.

For example take 98% Carbon-12u and 2% Carbon-13u

$$(12 \times \frac{98}{100}) + (13 \times \frac{2}{100}) = 12.02u$$

This does not mean that any Carbon atoms exists with the mass number of 12.02u. If you take a certain amount of Carbon, it will contain both isotopes of Carbon, and the average mass is 12.02 u.

Discovery of Protons and Neutrons

Discovery of Protons

The discovery of protons dates back to the year 1815 when the English chemist William Prout suggested that all atoms are made up of hydrogen atoms (which he referred to as protyles). When canal rays (positively charged ions formed by gases) were discovered by the German physicist Eugen Goldstein in the year 1886, it was observed that the charge-to-mass ratio of the hydrogen ion was the highest among all gases. It was also observed that the hydrogen ion had the smallest size among all ionized gases.

The nucleus of the atom was discovered by Ernest Rutherford in the year 1911 in his famous gold foil experiment. He concluded that all the positively charged particles in an atom were concentrated in a singular core and that most of the atom's volume was empty. He also stated that the total number of positively charged particles in the nucleus is equal to the total number of negatively charged electrons present around it.

Who Discovered Protons?

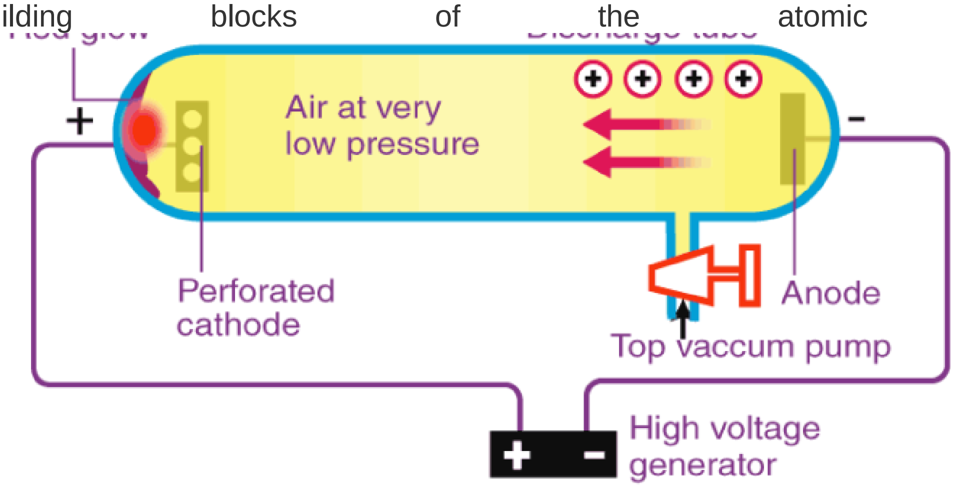
The discovery of the proton is credited to Ernest Rutherford, who proved that the nucleus of the hydrogen atom (i.e. a proton) is present in the nuclei of all other atoms in the year 1917.

Based on the conclusions drawn from the gold-foil experiment, Rutherford is also credited with the discovery of the atomic nucleus.

How was the Proton Discovered?

- Ernest Rutherford observed that his scintillation detectors detected hydrogen nuclei when a beam of alpha particles was shot into the air.
- After investigating further, Rutherford found that these hydrogen nuclei were produced from the nitrogen atoms present in the atmosphere.
- He then proceeded to fire beams of alpha particles into pure nitrogen gas and observed that a greater number of hydrogen nuclei were produced.
- He concluded that the hydrogen nuclei originated from the nitrogen atom, proving that the hydrogen nucleus was a part of all other atoms.
- This experiment was the first to report a nuclear reaction, given by the equation: $^{14}\mathbf{N} + \alpha \rightarrow {}^{17}\mathbf{O} + \mathbf{p}$ [Where α is an alpha particle which contains two protons and two neutrons, and 'p' is a proton]

- The hydrogen nucleus was later named ‘proton’ and recognized as one of the building blocks of the atomic nucleus.



Discovery of proton

Discovery of Neutrons

The discovery of neutrons can be traced back to the year 1930 when the German nuclear physicists Herbert Becker and Walther Bothe observed that a penetrating form of radiation was produced when the alpha particles emitted by polonium was incident on relatively light elements such as lithium, beryllium, and boron. This penetrating radiation was unaffected by electric fields and was, therefore, assumed to be gamma radiation.

In the year 1932, the French scientists Frederic Joliot-Curie and Irene Joliot-Curie observed that this unusually penetrating radiation, when incident on paraffin wax (or other compounds rich in hydrogen), caused the ejection of high energy protons (~5 MeV). The Italian physicist Ettore Majorana suggested the existence of a neutral particle in the nucleus of the atom which was responsible for the manner in which the radiation interacted with protons.

The presence of neutral particles in the nuclei of atoms was also suggested by Ernest Rutherford in the year 1920. He suggested that a neutrally charged particle, consisting of a proton and an electron bound to each other, also resided in the nuclei of atoms. He coined the term ‘neutron’ to refer to these neutrally charged particles.

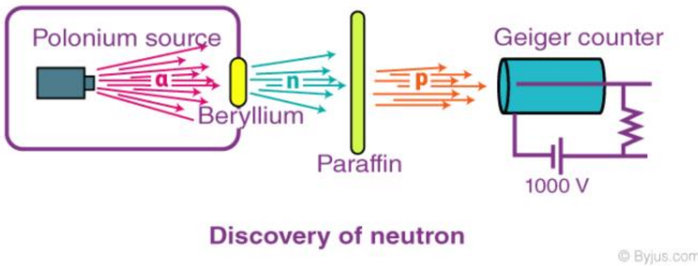
Who Discovered Neutrons?

The British physicist Sir James Chadwick discovered neutrons in the year 1932. He was awarded the Nobel Prize in Physics in the year 1935 for this discovery.

It is important to note that the neutron was first theorized by Ernest Rutherford in the year 1920.

How were Neutrons Discovered?

- James Chadwick fired alpha radiation at beryllium sheet from a polonium source. This led to the production of an uncharged, penetrating radiation.
- This radiation was made incident on paraffin wax, a hydrocarbon having a relatively high hydrogen content.
- The protons ejected from the paraffin wax (when struck by the uncharged radiation) were observed with the help of an ionization chamber.
- The range of the liberated protons was measured and the interaction between the uncharged radiation and the atoms of several gases was studied by Chadwick.
- He concluded that the unusually penetrating radiation consisted of uncharged particles having (approximately) the same mass as a proton. These particles were later termed ‘neutrons’.



Discovery of neutron