Loknete Dr.Balasaheb Vikhe Patil (Padma Bhushan Awardee)
Pravara Rural Education Society

Arts, Science & Commerce College, Kolhar

Tal-Rahata, Dist-Ahmednagar Pin-413710

NAAC Accredited at ‘A’ Grade With CGPA 3.10

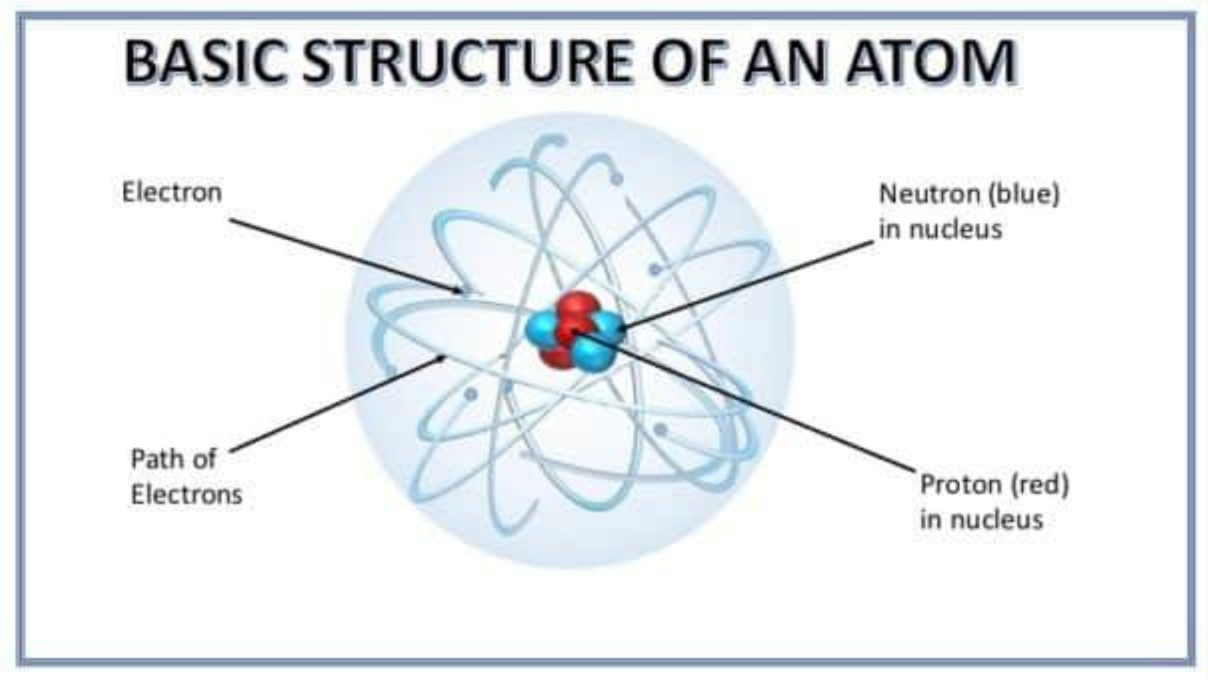
Department of Physics

Subject- Physics Principles and Application

1. PHYSICS OF ATOM

- Atoms are the basic building block of matter. They are the smallest particles, which has all the features and properties of that particular element.
- **BASIC STRUCTURE OF AN ATOM**
- According to the modern standard model, the basic structure of an atom is as follows:

1. An atom consists of the subatomic particles called electrons, protons and neutrons.
2. There are two parts of an atom – the nucleus and the orbits or the shells.

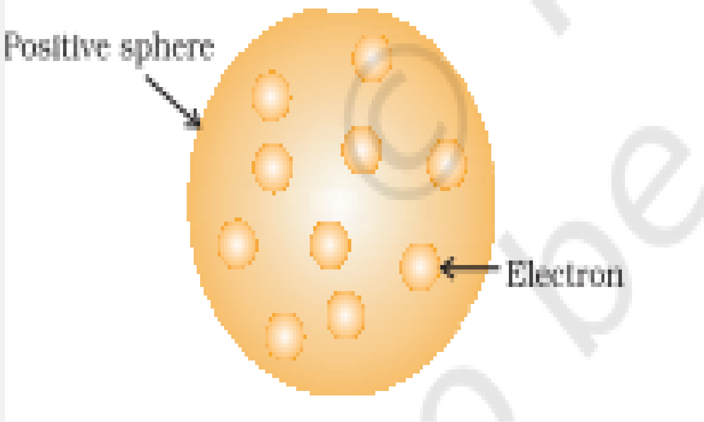


The nucleus is the central part of the atom. This consists of protons and neutrons.
Usually, an atom has the same number of protons and electrons. So, the positives and negatives are equal, which means the whole atom has no electrical charge.

ATOMIC MODELS

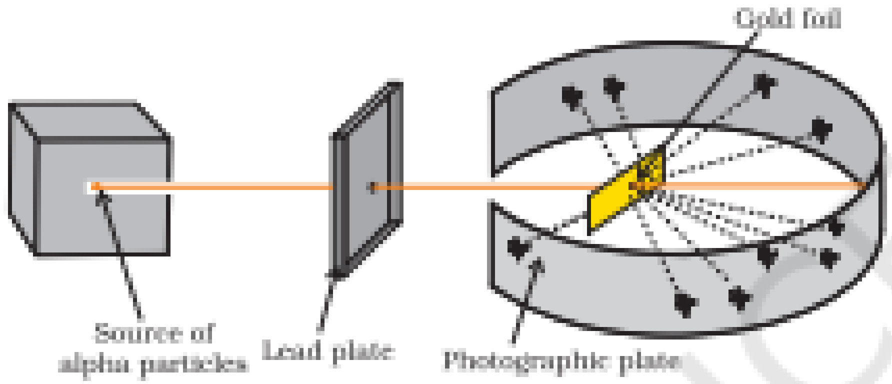
- Different atomic models were proposed to explain the distributions of these charged particles in an atom. Although some of these models were not able to explain the stability of atoms, two of these models, one proposed by J.J. Thomson and the other proposed by Ernest Rutherford are discussed below.

THOMSON MODEL OF ATOM

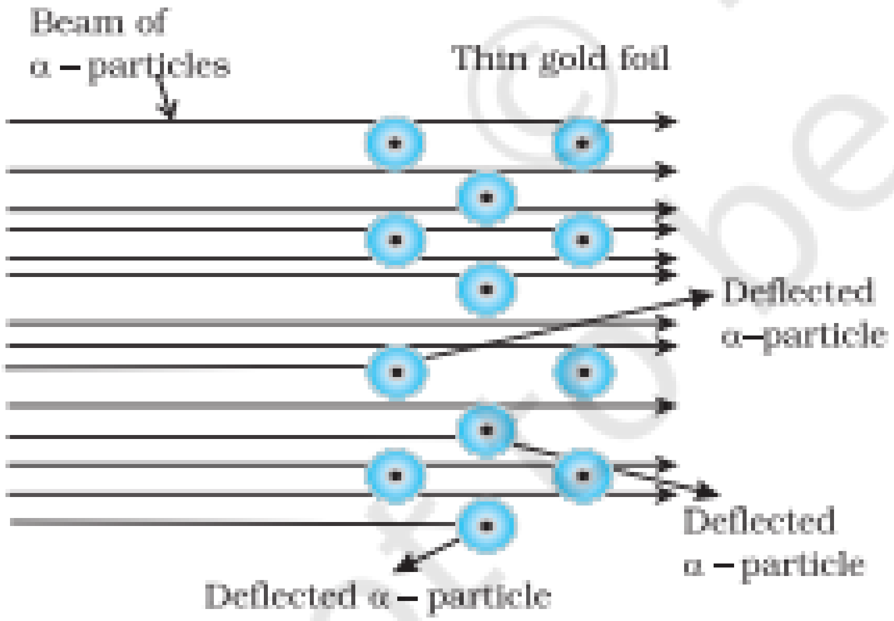


J. J. Thomson, in 1898, proposed that an atom possesses a spherical shape (radius approximately 10–10 m) in which the positive charge is uniformly distributed. The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement Many different names are given to this model, for example, plum pudding, raisin pudding or watermelon. This model can be visualized as a pudding or watermelon of positive charge with plums or seeds (electrons) embedded into it. An important feature of this model is that the mass of the atom is assumed to be uniformly distributed over the atom. Although this model was able to explain the overall neutrality of the atom, but was not consistent with the results of later experiments. Thomson was awarded Nobel Prize for physics in 1906, for his theoretical and experimental investigations on the conduction of electricity by gases.

RUTHERFORD'S NUCLEAR MODEL OF ATOM



A. Rutherford's scattering experiment



B. Schematic molecular view of the gold foil

- Rutherford and his students (Hans Geiger and Ernest Marsden) bombarded very thin gold foil with α–particles. Rutherford's famous α–particle scattering experiment is represented in Fig.. A stream of high energy α–particles from a radioactive source was directed at a thin foil (thickness ~ 100 nm) of gold metal. The thin gold foil had a circular fluorescent zinc sulphide screen around it. Whenever α–particles struck the screen, a tiny flash of light was produced at that point. The results of scattering experiment were quite unexpected. According to Thomson model of atom, the mass of each gold atom in the foil should have been spread evenly over the entire atom, and α–particles had enough energy to pass directly through such a uniform distribution of mass. It was expected that the particles would slow down and change directions only by a small angles as they passed through the foil. It was observed that: (i) most of the α–particles passed through the gold foil undeflected. (ii) a small fraction of the α–particles was deflected by small angles. (iii) a very few α–particles (~1 in 20,000) bounced back, that is, were deflected by nearly 180° . On the basis of the observations, Rutherford drew the following conclusions regarding the structure of atom: (i) Most of the space in the atom is empty as most of the α–particles passed through the foil undeflected. (ii) A few positively charged α–particles were deflected. The deflection must be due to enormous repulsive force showing that the positive charge of the atom is not spread throughout the atom as Thomson had presumed. The positive charge has to be concentrated in a very small volume that repelled and deflected the positively charged α–particles. (iii) Calculations by Rutherford showed that the volume occupied by the nucleus is negligibly small as compared to the total volume of the atom. The radius of the atom is about 10–10 m, while that of is 10–15 m. One can appreciate this difference in size by realising that if a cricket ball represents a nucleus, then the radius of atom would be about 5 km.

On the basis of above observations and conclusions, Rrutherford proposed the nuclear model of atom

- According to this model:
- (i) The positive charge and most of the mass of the atom was densely concentrated in extremely small region. This very small portion of the atom was called nucleus by Rutherford.
- (ii) The nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called orbits. Thus, Rutherford's model of atom resembles the solar system in which the nucleus plays the role of sun and the electrons that of revolving planets.
- (iii) Electrons and the nucleus are held together by electrostatic forces of attraction.

DRAWBACKS OF RUTHERFORD MODEL

- Stability of Atom:

The similarity between the solar system and nuclear model suggests that electrons should move around the nucleus in well defined orbits. Further, the coulomb force (kq1q2/r2 where q1 and q2 are the charges, r is the distance of separation of the charges and k is the proportionality constant) between electron and the nucleus is mathematically similar to the gravitational force. However, when a body is moving in an orbit, it undergoes acceleration even if it is moving with a constant speed in an orbit because of changing direction. So an electron in the nuclear model describing planet like orbits is under acceleration. According to the electromagnetic theory of Maxwell, charged particles when accelerated should emit electromagnetic radiation (This feature does not exist for planets since they are uncharged). Therefore, an electron in an orbit will emit radiation, the energy carried by radiation comes from electronic motion. The orbit will thus continue to shrink. Calculations show that it should take an electron only 10–8 s to spiral into the nucleus. But this does not happen. Thus, the Rutherford model cannot explain the stability of an atom. If the motion of an electron is described on the basis of the classical mechanics and electromagnetic theory, you may ask that since the motion of electrons in orbits is leading to the instability of the atom then why not consider electrons as stationary around the nucleus. If the electrons were stationary, electrostatic attraction between the dense nucleus and the electrons would pull the electrons toward the nucleus to form a miniature version of Thomson's model of atom.

- Another serious drawback of the Rutherford model is that it says nothing about distribution of the electrons around the nucleus and the energies of these electrons

BOHR'S MODEL FOR HYDROGEN ATOM

- Neils Bohr (1913) was the first to explain quantitatively the general features of the structure of hydrogen atom and its spectrum. He used Planck's concept of quantisation of energy. Though the theory is not the modern quantum mechanics, it can still be used to rationalize many points in the atomic structure and spectra. Bohr's model for hydrogen atom is based on the following postulates:
- i) The electron in the hydrogen atom can move around the nucleus in a circular path of fixed radius and energy. These paths are called orbits, stationary states or allowed energy states. These orbits are arranged concentrically around the nucleus.
- ii) The energy of an electron in the orbit does not change with time. However, the electron will move from a lower stationary state to a higher stationary state when required amount of energy is absorbed by the electron or energy is emitted when electron moves from higher stationary state to lower stationary state. The energy change does not take place in a continuous manner.
- iii) The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by:
- $v = \Delta E / h$
- $=(E2- E1)/ h$
- E1 and E2 are the energies of the lower and higher allowed energy states respectively. This expression is commonly known as Bohr's frequency rule.
- iv) The angular momentum of an electron is quantised. In a given stationary state it can be expressed as in equation
- $m\,vr=n\,h/ 2\pi$. $n = 1,2,3....$