Thomson's Model of an Atom

All of us have seen a plum pudding and a watermelon in our daily life. Do you know one of the early models of an atom has been compared to a plum pudding, raisin pudding, and even a watermelon? The model we are talking about is the Thomson's atomic model. Any idea why it has been given such names? Let us find out more about Thomson's atomic model or Thomson's Model of an Atom.

History

Before the discovery of subatomic particles, John Dalton came up with Dalton's atomic theory where he suggested that atoms are indivisible particles. It explained atoms cannot be broken down into further smaller particles. However, the discovery of subatomic particles disapproved the postulates proposed in Dalton Atomic Theory.

The discovery of subatomic particles led to the search how the subatomic particles are arranged in an atom. J.J. Thomson was the first and one of the many scientists who proposed models for the structure of an atom. J.J. Thomson discovered negatively charged particles by cathode ray tube experiment in the year 1897.

The particles were named electrons. J.J Thomson believed electrons to be two thousand times lighter than a proton. He assumed that an atom is composed of a cloud of negative charge in a sphere of positive charges. J.J Thomson and Rutherford first demonstrated the ionization of air in x rays.

Thomson Model of an atom

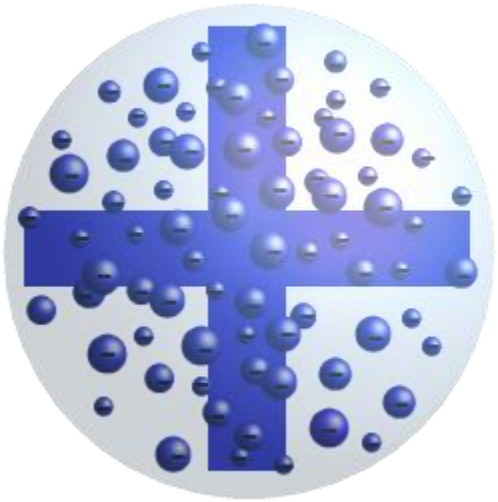
The description of Thomson's atomic model is one of the many scientific models of the atom. It was proposed by J.J Thomson in the year 1904 just after the discovery of electrons. However, at that time the atomic nucleus was yet to be discovered. So, he proposed a model on the basis of known properties available at that time. The known properties are:

- Atoms are neutrally charged
- Negatively charged particles called electrons are present in an atom. Learn about Charged particles in Matter in more detail here.

Thomson's Atomic Model- Postulates

- 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 resembles a spherical plum pudding as well as a watermelon. It resembles a plum pudding because the electrons in the model look like the dry fruits embedded in a sphere of positive charge just like a spherical plum pudding. The model has also been compared to a watermelon because the red edible part of a watermelon was compared to the sphere having a positive charge and the black seeds filling the watermelon looked similar to the electrons inside the sphere.



Limitations of Thomson's Atomic Model

- 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.
- It was unable to explain the scattering experiment of Rutherford.

Conclusion

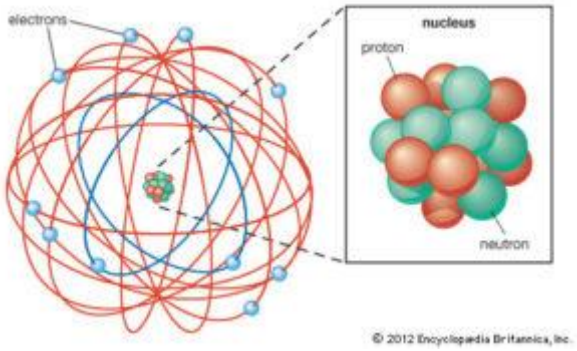
Even though Thomson's atomic model was inaccurate and had a few drawbacks, it provided the base for several other atomic structure models afterward. It is one of the foundation models that led to significant and revolutionary inventions later.

Rutherford's Model of an Atom

We know a structure of an atom consists of electrons, protons, and neutrons. This was accurately presented after several scientists came up with different models. The classic model of an atom was given by Ernest Rutherford called the Rutherford atomic model or Rutherford model of the atom. However, it is not considered the accurate representation of an atom anymore. Let us know more about this model.

Rutherford Atomic Model

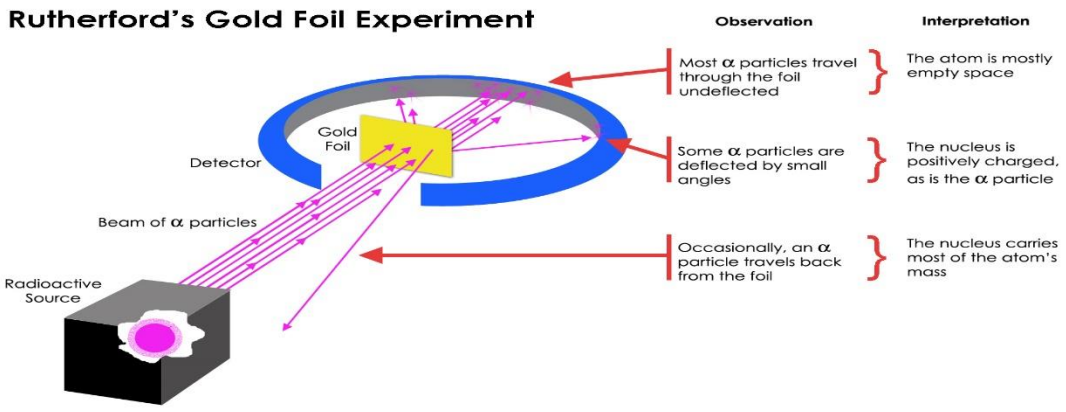
Rutherford proposed that an atom is composed of empty space mostly with electrons orbiting in a set, predictable paths around fixed, positively charged nucleus.

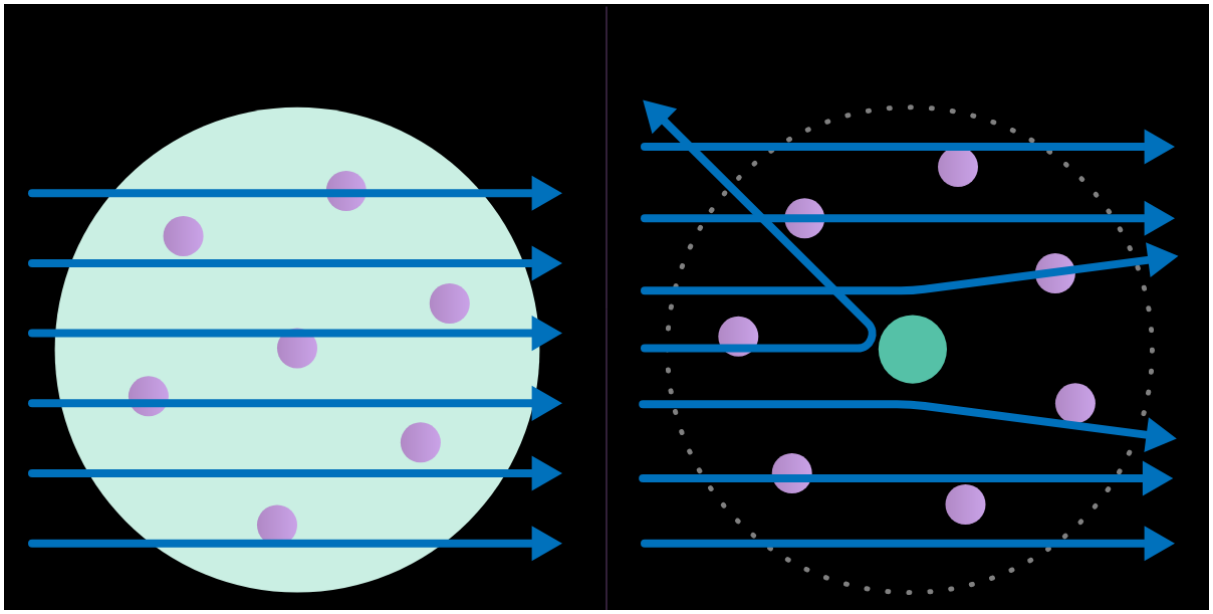


A British Physicist "Ernest Rutherford" proposed a model of the atomic structure known as Rutherford's Model of Atoms. He conducted an experiment where he bombarded α-particles in a thin sheet of gold. In this experiment, he studied the trajectory of the α-particles after interaction with the thin sheet of gold.

Rutherford Atomic Model Experiment

In Rutherford's experiment, he bombarded high energy streams of α-particles on a thin gold foil of 100 nm thickness. The streams of α-particles were directed from a radioactive source. He conducted the experiment to study the deflection produced in the trajectory of α-particles after interaction with the thin sheet of gold. To study the deflection, he placed a screen made up of zinc sulfide around the gold foil. The observations made by Rutherford contradicted the plum pudding model given by J.J. Thomson.





Observations of Rutherford Model Experiment

On the basis of the observations made during the experiment, Rutherford concluded that

- Major space in an atom is empty – A large fraction of α-particles passed through the gold sheet without getting deflected. Therefore, the major part of an atom must be empty.
- The positive charge in an atom is not distributed uniformly and it is concentrated in a very small volume – Few α-particles when bombarded were deflected by the gold sheet. They were deflected minutely and at very small angles. Therefore he made the above conclusion.
- Very few α-particles had deflected at large angles or deflected back. Moreover, very few particles had deflected at 180^{o}. Therefore, he concluded that the positively charged particles covered a small volume of an atom in comparison to the total volume of an atom.

Postulates of Rutherford atomic model based on observations and conclusions

- An atom is composed of positively charged particles. Majority of the mass of an atom was concentrated in a very small region. This region of the atom was called as the **nucleus** of an atom. It was found out later that the very small and dense nucleus of an atom is composed of neutrons and protons.
- Atoms nucleus is surrounded by negatively charged particles called **electrons**. The electrons revolve around the nucleus in a fixed circular path at very high speed. These fixed circular paths were termed as **"orbits."**
- An atom has no net charge or they are **electrically neutral** because electrons are negatively charged and the densely concentrated nucleus is positively charged. A strong electrostatic force of attractions holds together the nucleus and electrons.
- The size of the nucleus of an atom is very small in comparison to the total size of an atom.

Limitations of Rutherford Atomic Model

Rutherford's experiment was unable to explain certain things. They are:

- Rutherford's model was unable to explain the stability of an atom. According to Rutherford's postulate, electrons revolve at a very high speed around a nucleus of an atom in a fixed orbit. However, Maxwell explained accelerated charged particles release electromagnetic radiations. Therefore, electrons revolving around the nucleus will release electromagnetic radiation.
- The electromagnetic radiation will have energy from the electronic motion as a result of which the orbits will gradually shrink. Finally, the orbits will shrink and collapse in the nucleus of an atom. According to the calculations, if Maxwell's explanation is followed Rutherford's model will collapse with 10^{-8} seconds. Therefore, Rutherford atomic model was not following Maxwell's theory and it was unable to explain an atom's stability.
- Rutherford's theory was incomplete because it did not mention anything about the arrangement of electrons in the orbit. This was one of the major drawbacks of Rutherford atomic model.

Bohr's Model of Atom

Quantum mechanics, Quantum physics, the theory of relativity, etc are the modern subjects that interests, astound, and confuse almost everybody. These topics form the basis of modern physics. However, the very first-time quantum theory was incorporated in Bohr's Model of an atom or Bohr atomic model. Later this model became the predecessor of complete quantum mechanical models.

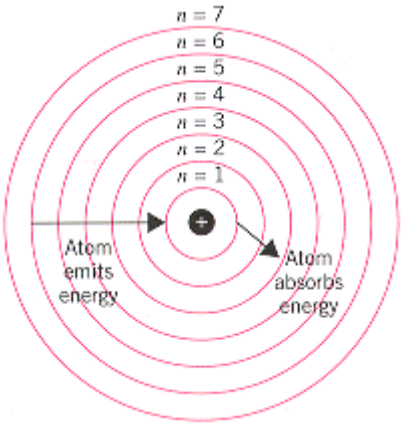
Bohr atomic model and the models after that explain the properties of atomic electrons on the basis of certain allowed possible values. The model explained how an atom absorb or emit radiation when electrons on subatomic level jump between the allowed and stationary states. German-born physicists James Franck and Gustav Hertz obtained the experimental evidence of the presence of these states.

Bohr Atomic Model

A Danish physicist named Neil Bohr in 1913 proposed the Bohr atomic model. He modified the problems and limitations associated with Rutherford's model of an atom. Earlier in Rutherford Model, Rutherford explained in an atom a nucleus is positively charged and is surrounded by electrons (negatively charged particles).

he electrons move around in a predictable path called **orbits**. Bohr modified Rutherford's model where he explained that electrons move around in fixed orbital shells. Furthermore, he explained that each orbital shell has fixed energy levels. Therefore, Rutherford basically explained a nucleus of an atom whereas Bohr took the model one step ahead. He explained about electrons and the different energy levels associated with it.

According to Bohr Atomic model, a small positively charged nucleus is surrounded by revolving negatively charged electrons in fixed orbits. He concluded that electron will have more energy if it is located away from the nucleus whereas the electrons will have less energy if it located near the nucleus.



Postulates of the Bohr Atomic Model

- Electrons revolve around the nucleus in a fixed circular path termed "orbits" or "shells" or "energy level."

- The orbits are termed as “stationary orbit.”
- Every circular orbit will have a certain amount of fixed energy and these circular orbits were termed orbital shells. The electrons will not radiate energy as long as they continue to revolve around the nucleus in the fixed orbital shells.
- The different energy levels are denoted by integers such as n=1 or n=2 or n=3 and so on. These are called as quantum numbers. The range of quantum number may vary and begin from the lowest energy level (nucleus side n=1) to highest energy level. Learn the concept of an Atomic number here.
- The different energy levels or orbits are represented in two ways such as 1, 2, 3, 4… or K, L, M, N….. shells. The lowest energy level of the electron is called the ground state. Learn the concept of Valency here in detail here.
- The change in energy occurs when the electrons jump from one energy level to other. In an atom, the electrons move from lower to higher energy level by acquiring the required energy. However, when an electron loses energy it moves from higher to lower energy level.

Therefore,

- 1^{st} orbit (energy level) is represented as K shell and it can hold up to 2 electrons.
- 2^{nd} orbit (energy level) is represented as L shell and it can hold up to 8 electrons.
- 3^{rd} orbit (energy level) is represented as M shell and it can contain up to 18 electrons.
- 4^{th} orbit (energy level) is represented as N Shell and it can contain maximum 32 electrons.

The orbits continue to increase in a similar manner.

Distribution of Electrons in Orbits or Shells:

Electronic distribution of various orbits or energy levels can be calculated by the formula $\mathbf{2n^2}$**.** Here, **‘n’** denotes the number of orbits.

- The number of electrons in K shell (1st orbit) can be calculated by $2n^2 = 2 \times 1^2 = 2$. Thus, maximum number of electrons in 1st orbit = 2
- Similarly, The number of electrons in L shell (2nd orbit)= $2 \times 2^2 = 8$. Thus, maximum number of electrons in 2nd orbit = 8

We can determine the maximum number of electrons in a similar way.

Limitations of Bohr’s Model of an Atom:

Bohr atomic model had few limitations. They are:

- Failure to explain Zeeman Effect (how atomic spectra are affected by magnetic fields).

- It contradicts Heisenberg Uncertainty Principle.
- Unable to explain how to determine the spectra of larger atoms.