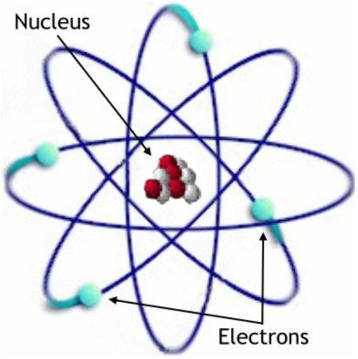
A brief history of Atoms

We currently believe that the **atom** is the basic unit of matter which consists of a dense nucleus surrounded by a cloud of negatively charged electrons. The nucleus contains a mix of positively charged protons and electrically neutral neutrons.



An atom containing an equal number of protons and electrons is electrically neutral; otherwise it has a positive charge (electron deficiency) or negative charge (electron excess) and is an ion.

This atomic model has been developed over thousands of years.

Atoms B.C.

The Greek scientist Aristotle (384 BC - 322 BC) proposed that all matter is made of five elements:

- Fire, which is hot and dry.
- Earth, which is cold and dry.
- Air, which is hot and wet.
- Water, which is cold and wet.
- Aether, which is the divine substance that makes up the heavenly spheres and heavenly bodies (stars and planets).

However other Greek scientists believed that that matter is composed of tiny undividable particles has been around for a long time.

The atomic ideas of Leucippus and Democritus (from about 440 BC) led Hero of Alexandria (150 A.D.) to make use of atoms to explain compression and rarefaction (in sound waves). Hero's model had a vacuum between atoms. One proof he cited was that fire could enter into a material, showing that it had openings. *There are spaces between atoms.*

Atomism in the middle Ages

The works of Greek scientists including Aristotle were rediscovered by Western Europe about 1200 in Latin translations of Arabic translations from Greek translations. Much discussion followed among such people as St. Thomas Aquinas (1225 - 74) and Roger Bacon (1214 - 92).

The Catholic Church began to elevate Aristotle's writings to the same level as Scripture and associated atomic thinking with Godlessness.

At age 21, Peter Ramus (1515 - 1572) presented a thesis based on the idea: "all that Aristotle has said is false." After attacking Aristotle's ideas for a whole day and being refuted, Ramus was finally awarded his degree with honours. In 1543, he wrote two books (against Aristotle) that provoked violent reaction. Their publication was banned, the books were burned, and Ramus was silenced by order of the Pope, Francis I. After the Pope died a year later, Ramus resumed teaching and was appointed professor in 1551.

Dalton's Atomic Theory:

John Dalton (1766 - 1844) was born into a modest Quaker family in England.
He earned his living for most of his life as a teacher and public lecturer.

The model of the atom proposed by Dalton:

- *Elements are made of tiny particles called atoms*
- *All atoms of a given element are identical.*
- *Atoms cannot be divided into smaller particles - they are* ***indivisible.***
- *There are spaces between atoms.*

As a Quaker, Dalton led a modest existence, although he received many honours later in life. In Manchester more than forty thousand people marched in his funeral procession.

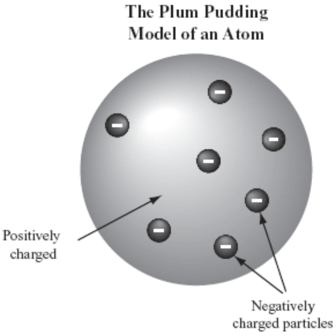
J. J. Thomson's plum pudding model:

Towards the end of the nineteenth century, the English physicist, J.J. Thomson (1856 – 1940) used a Crookes tube and discovered the existence of a subatomic particle - the electron.

The Crookes tube consisted of a partially evacuated glass cylinder of various shapes, with two metal electrodes, one at either end. When a high voltage is applied between the electrodes, electrons travel in straight lines from the cathode to the anode creating a spooky green glow. In 1897 J.J. Thomson used the apparatus to identify the cathode rays as negatively-charged particles, which were later named electrons.

J.J. Thomson found these electrons to be particles which carried electrical charge but more importantly they had a mass at least a thousand times smaller than a hydrogen atom. The conclusion from this was that there are particles smaller than atoms and so an atom must not be the fundamental or smallest particle!!!

It had been suspected for some time that atoms consisted of electrically charged particles held together by electrical forces but the actual structure was only vaguely understood.



The plum pudding model of the atom proposed by J. J. Thomson:

- *Electrons are like negative 'plums' embedded in a 'pudding' of positive matter.*
- *The negative charges of the electrons are balanced out by the positive charges in the atoms making the atom overall neutral.*
- *There are spaces between atoms.*

The Rutherford model:

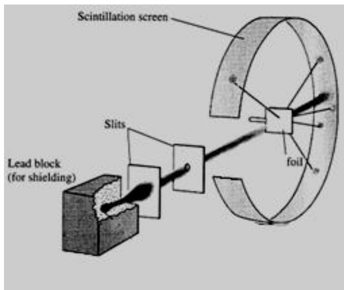
The Rutherford model of the atom was devised by New Zealander Ernest Rutherford (1871-1937). In 1894, Rutherford was awarded a scholarship to study at Trinity College, Cambridge, with famed physicist J. J. Thomson.

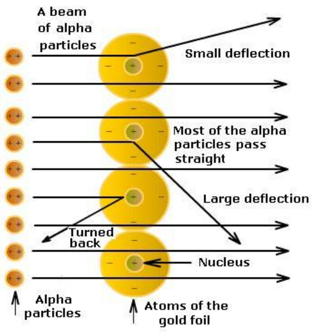
Rutherford's famous gold foil experiment showed that the Plum pudding model of the atom was incorrect (even though it was meant to be proving it).

In 1909, Hans Geiger and Ernest Marsden, under the direction of Rutherford, carried out an experiment to investigate bombarded a thin sheet of gold foil only a few atoms thick placed in a vacuum with alpha rays.

Rutherford and Geiger had already discovered that alpha particles were positively charged helium ions.

It was discovered that a small percentage of these particles were deflected through much larger angles than was predicted using Thomson's plum pudding model.

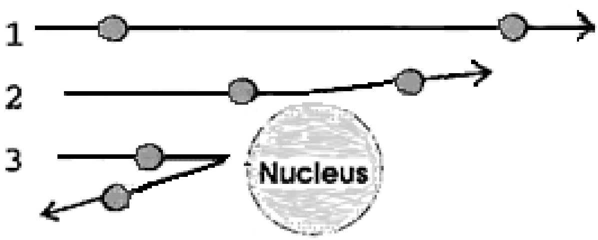




It had expected that most of the alpha particles would pass through the thin foil or only be deflected slightly. This actually happened most of the time, but a few particles, 1 in 8000, bounced back towards the source. These results led to Rutherford's 1911 hypothesis that the atom consisted of a hard core (named the *nucleus* in 1912) that contained almost all the mass of the atom and had a positive charge, and that the electrons, which had little mass and a negative charge, orbited the core at a distance.

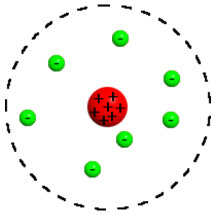
Rutherford's evidence and conclusions in more detail:

Evidence from the alpha particle scattering	Conclusion about the gold atoms
1. **Most** positive α particles are deflected **by less** than 5°	There is a lot of empty space in the atom/there is a small nucleus in the atom (because most alpha particles did not hit anything)
2. **Some** of the positive α particles are **deflected/repelled**	The nucleus had a positive charge (because the positive alpha particles are deflected/repelled by the positive nucleus)
3. **A few** of the positive α particles **bounce back**	The nucleus was dense/massive (because the light alpha particles bounce back from the much more massive gold nuclei)



The model of the atom proposed by Rutherford:

- *The atom is neutral overall*
- *The atom is made up of a positive nucleus consisting of protons*
- *The nucleus is surrounded by a cloud of orbiting electrons.*
- *There are spaces within atoms.*



Analysis of the experimental results showed that the nucleus must be about 1/4000 of the size of the atom. This is roughly equivalent to the nucleus being the size of a peanut in the middle of an atom of the size of the Athletics Track at Cooks Gardens in Wanganui.

At this point, the Rutherford model did not attribute any structure to the orbiting electrons and it did not include neutrons.

The Rutherford-Bohr model

Rutherford's model still required further development.

As electrons were thought to be moving in circular orbits around the nucleus, the electrons are constantly accelerating. Constantly accelerating charged particles create magnetic fields requiring energy. This means that the electrons should lose energy and spiral into the nucleus. It also means that as the electrons slow down they should emit a continuous spectrum but neither of these happen.

In 1912 the Danish physicist Niels Bohr (1885–1962) arrived in England to work with Rutherford. Bohr and Rutherford developed the model further by suggesting that the electrons circle the nucleus at high speed and are kept in certain orbits in a stable formation around the atomic nucleus.

In 1932 James Chadwick discovered the neutron. A decade earlier at the Cavendish Laboratory Rutherford had predicted its existence and had indicated to Chadwick what properties the neutron must have.

The Rutherford-Bohr atom features in chemistry and physics books used world-wide and Rutherford scattering is still used today to probe sub-nuclear particles and the structure of micro-electronic devices.

These models began a new approach to science because for the first time rules had to fit the observation regardless of how they conflicted with the theories of the time.

But the atomic model continues to develop in terms of models such as string theory…

Task – Models of the structure of the atom

Introduction:

Our understanding of the physical world has grown at an incredible rate in the last 200 years. The key to the advances made in physics has been our growing knowledge about atoms. In this assessment, you will report on a crucial development that advanced our understanding of the atom.

JJ Thomson carried out an experiment that lead to the discovery of the electron and used this to create a new model of the atom. Thomson's model of the atom was revised as a result of the gold foil experiment carried out by the New Zealander Ernest Rutherford and his assistants, Geiger and Marsden. The findings of this experiment led to Rutherford's revised model of the atom. Rutherford's model, itself, was replaced by the Rutherford-Bohr model.

Research into refining our understanding of the atom continues.

Task:

Write a short report that illustrates how our understanding of the atom advanced from Dalton's model to Thompson's model of the atom to Rutherford's model of the atom to the Rutherford-Bohr model of the atom.

Your report should:

- Provide a description of the key points of Dalton's model.
- Provide a description of the experiment that Thomson carried out to discover the electron. Explain in detail how this experiment led Thomson to develop his model of the atom. Explain the key points of Thomson's model.
- Provide a description of the gold foil experiment that Rutherford and his associates carried out to further investigate the structure of the atom. Explain in detail how the findings of the gold foil experiment were incorporated in the Rutherford model of the atom. Explain the key points of Thomson's model.
- Describe the limitations of the Rutherford-Bohr model of the atom. Explain why these limitations implied further research was required.