Key Historical Developments and Experiments that reveal Atoms and Atomic Structure

The idea of the atom is developed:

- Around 400 B.C. Greek philosophers Leucippus and Democritus asserted that all material things are composed of extremely tiny, indivisible particles called ***atoms***. "*Nothing exists except atoms and empty space. Everything else is opinion*". The atomic theory was rejected by Aristotle, and thus by almost everyone else for the next two millennia.

- Antoine Lavoisier (in 1789) formulates and states the ***Law of Conservation of Mass***. He demonstrated this via some of the first quantitative experiments of the time. By carefully weighing the reactants and products in chemical reactions, he showed that the total mass of matter remains constant during the reaction (mass before reaction equals mass after reaction). Lavoisier also performs a quantitative study of combustion and elucidates the role of oxygen in this process.

- Joseph Louis Proust (in 1799) studies the composition of compounds and develops the ***Law of Definite Proportions***. This law states that if a compound is broken down into its constituent elements, the masses of the elements will always occur in fixed proportions, regardless of the quantity or source of the original substance.

- John Dalton (in 1805) proposes his ***Atomic Theory*** to explain the results of Lavoisier and Proust, as well as his own experiment work and that of many other scientists.

Dalton's Atomic Theory

a. Elements consist of tiny, indivisible particles called atoms.

b. All the atoms of a given element are identical, however, the atoms of different elements differ in some fundamental way.

c. Compounds form when atoms of different elements combine in simple whole number ratios. Thus, a given compound always contains the same relative number and types of atoms.

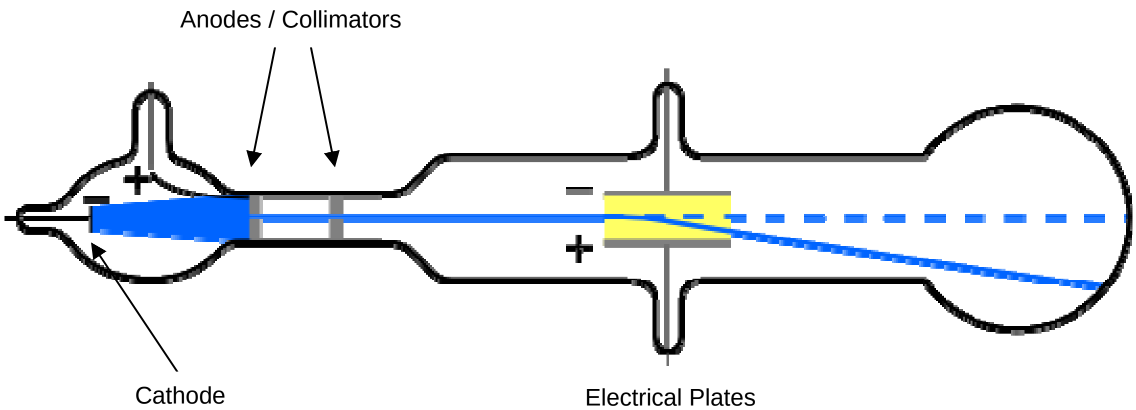
d. During a chemical reaction, atoms are neither created nor destroyed. Instead, reactions involve the reorganization of the atoms – a change in the way they are grouped together. The atoms themselves are unaltered.

This was the first truly scientific theory of the atom, since Dalton reached his conclusions by experimentation and examination of the results in an empirical manner.

The internal structure of atoms is discovered:

- Several important experiments reveal that the atom is divisible. Atoms are found to be composed of ***subatomic particles***: protons, neutrons and electrons, all with specific arrangements within the atom.

- J.J. Thomson (in 1896) performs experiments with ***Cathode Ray Tubes*** (CRT) and discovers the electron. The figure below is a simple schematic diagram of a CRT. The original device used by Thomson was about one meter in length, and was made entirely by hand.

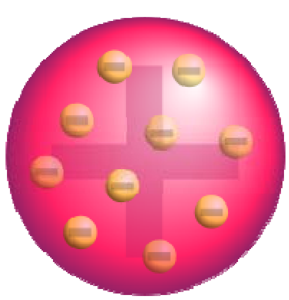


The entire glass tube was evacuated down to as low a vacuum as could be produced (at that time), then sealed. Two electrical plates were placed about midway in the CRT (connected to a powerful electric battery), through which the cathode rays were passed. Thomson also used magnets, which were placed on either side of the straight portion of the tube just to the right of the electrical plates. This allowed him to use either electrical or magnetic fields (or a combination of both) to cause the cathode rays to bend. Thomson discovered that:

► Rays originate from the cathode (negative electrode) and travel to the anode (positive electrode).
► The rays consist of a stream of particles which have mass.
► The particles in the rays have negative charge.
► The same particles are generated no matter what material is used for the cathode.

Thomson called these particles "corpuscles". We now call these particles ***electrons***. They are present in all atoms.

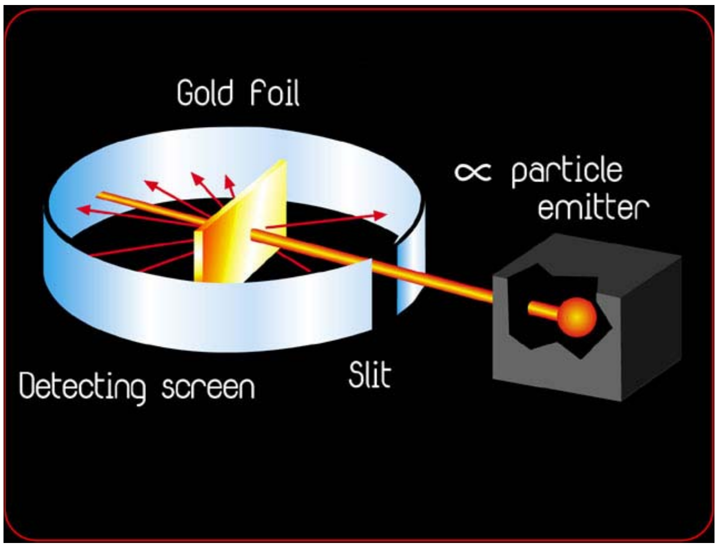
- Thomson (in 1904) proposes the ***Plum Pudding Model*** of the atom: An atom consists of diffuse positive charge with negatively charged electrons imbedded in it, like raisins in a pudding.

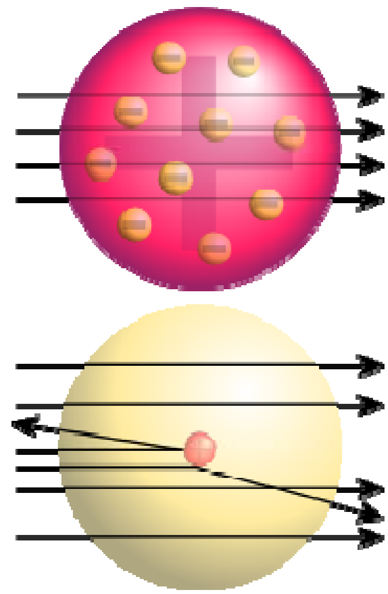


- Radioactivity is discovered. Three types of radiation are identified:

  - ► α rays (alpha rays) = tiny, heavy particles with a positive charge and high velocity
  - ► β rays (beta rays) = very high speed electrons
  - ► γ rays (gamma rays) = no mass, no charge, similar to x-rays but shorter wavelength

- Ernest Rutherford (in 1909) discovers the nucleus of the atom and demonstrates that the Plum Pudding Model is incorrect. His experiment is called the ***Gold Foil Experiment*** (or Geiger-Marsden experiment). A schematic diagram of this experiment is shown below.





Rutherford and his team (Geiger and Marsden) bombarded a number of different thin metal foils with α rays – tiny, heavy particles with a positive charge. Particles passing through the foil would strike a screen coated with zinc sulfide, and appear as tiny flashes of light.

Given the very high mass and momentum of the α-particles, the expectation was that the particles would pass through the foil and be scattered by tiny angles at most. However, to their amazement, a few (~1 in 8000 particles) were deflected by large angles (greater than 90°), an observation completely at odds with the predictions of the Plum Pudding Model.

Based on his analysis of these scattering results, Rutherford proposes a revised model of the atom called the ***Nuclear Model*** of the atom. In this model, all the positive charge and most of the atomic mass is concentrated at the center of the atom – in the nucleus – while electrons "orbit the nucleus, like planets orbit the sun.

- Rutherford (in 1918) was able to experimentally identify particles with positive charge in the nucleus, which he called ***protons***. But although he could explain the charge of atomic nuclei with the right number of protons, the mass of an atom's nucleus was always larger than the sum of its protons. Therefore he postulated the existence of a neutral particle with a mass nearly the same as the proton which, when added to the protons in the nucleus, would give the right mass. Rutherford called this hypothetical particle the ***neutron***. Much later, James Chadwick (in 1930) was able to detect the neutron experimentally.