

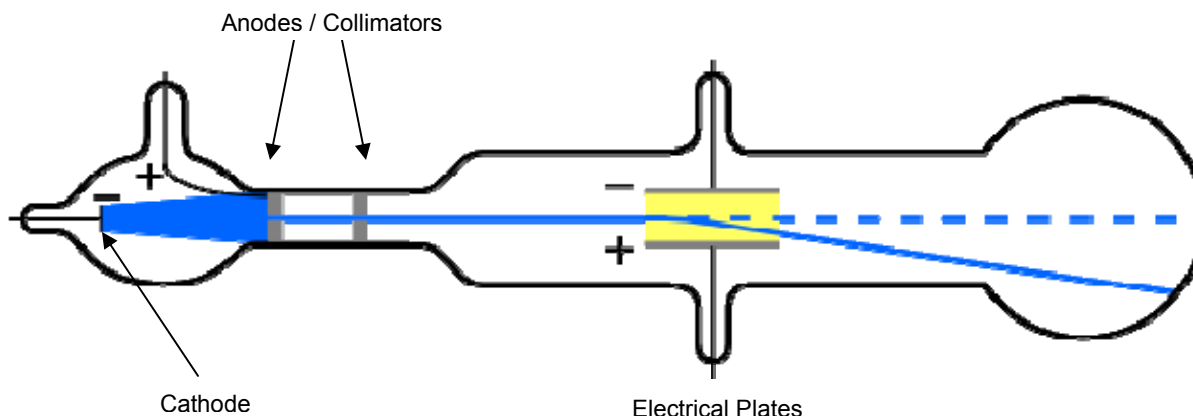
Experiments that revealed the Structure of the Atom

- From the late 1800s to the early 1900s, several experiments were performed that revealed the internal structure of the atom. To design these sophisticated experiments, scientists had to employ electricity, magnetism and radioactive materials (all which were discovered and extensively studied during the 1800s).
- Scientists eventually determine that atoms consist of 3 subatomic particles:
 - ▶ electrons: tiny negatively charged particles
 - ▶ protons: heavy positively charged particles
 - ▶ neutrons: heavy particles carrying no electrical charge

where the protons and neutrons occupy the small, dense center of the atom called the atomic nucleus.

Thomson and Cathode Ray Tubes

- 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.

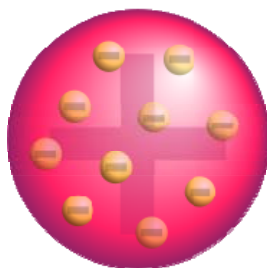


The entire glass tube was evacuated down to as low a vacuum as could be produced, then sealed. Two electrical plates were placed about midway in the CRT (connected to a powerful electric battery), through which the cathode rays were passed. Thomson also used magnets, which were placed on either side 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:

- ▶ The 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 particles are generated no matter what material is used for the cathode.
- ▶ The charge to mass ratio of the particles, $e/m = -1.76 \times 10^8 \text{ C/g}$.

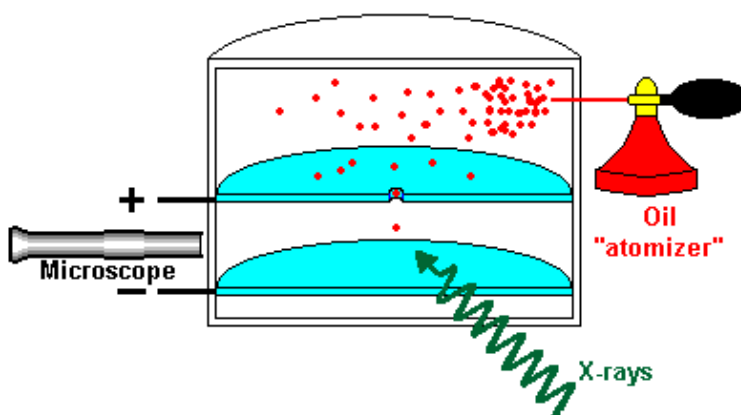
Thomson called these particles “corpuscles”. We now call these particles **electrons**. They are present in all atoms.

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



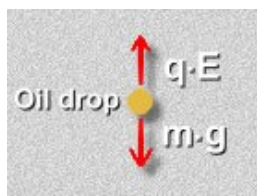
Millikan and the Oil Drop Experiment

- Robert Millikan (in 1909) measures the charge on one electron. His experiment is called the Millikan Oil Drop Experiment. A figure of the apparatus he used is shown below.



Charged oil droplets were allowed to fall between two electrical plates that supply a uniform electric field. The droplets were generated by an atomizer and a negative charge was applied by irradiating them with X-rays. The potential of the electric field was adjusted so that instead of falling, a drop would be suspended between the plates in mid-air. The gravitational and electric forces on the charged droplets are thus balanced.

When a drop is suspended, its weight $m \cdot g$ is exactly equal to the electric force applied $q \cdot E$. The values of E , the applied electric field, m the mass of a drop, and g , the acceleration due to gravity, are all known values. So Millikan was able to solve for q , the charge on the drop:



$$q \cdot E = m \cdot g$$

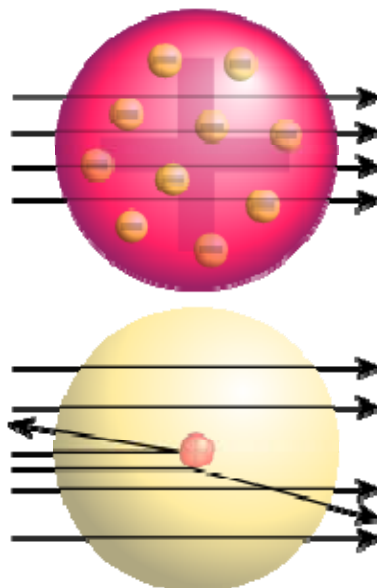
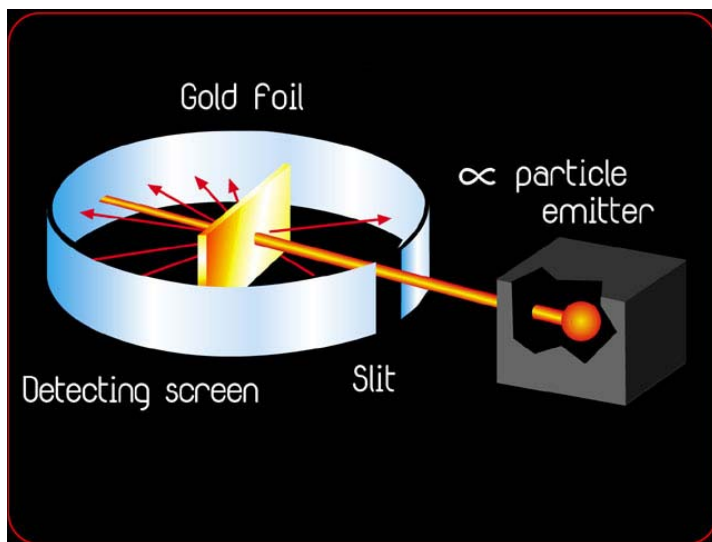
$$q = \frac{m \cdot g}{E}$$

Repeating the experiment for many droplets, he discovered that the values measured were always multiples of the same number. This number was determined to be the charge on a single electron: 1.602×10^{-19} Coulombs.

Finally, using this value and the e/m ratio determined by Thomson, Millikan was able to calculate the mass of an electron ($= 9.11 \times 10^{-31}$ kg).

Rutherford and the Gold Foil Experiment

- 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 alpha (α) particles from a radioactive source. Alpha particles are 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 they would pass through the foil and be scattered by tiny angles at most. However, 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.