Atomic Structure is Gradually Discovered

The Electron Comes First

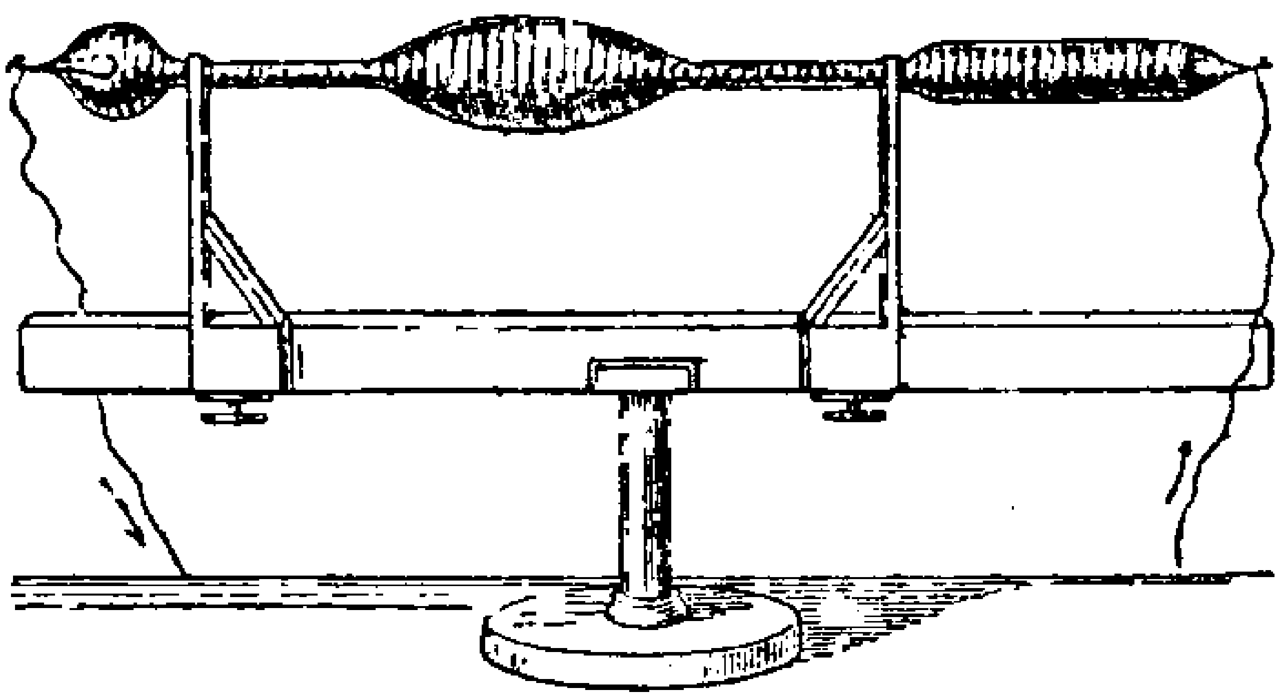
In the mid 1800's some physicists were doing electricity experiments.
Their experiments involved passing high voltage electricity through evacuated glass tubes.

Heinrich Geissler 1850's

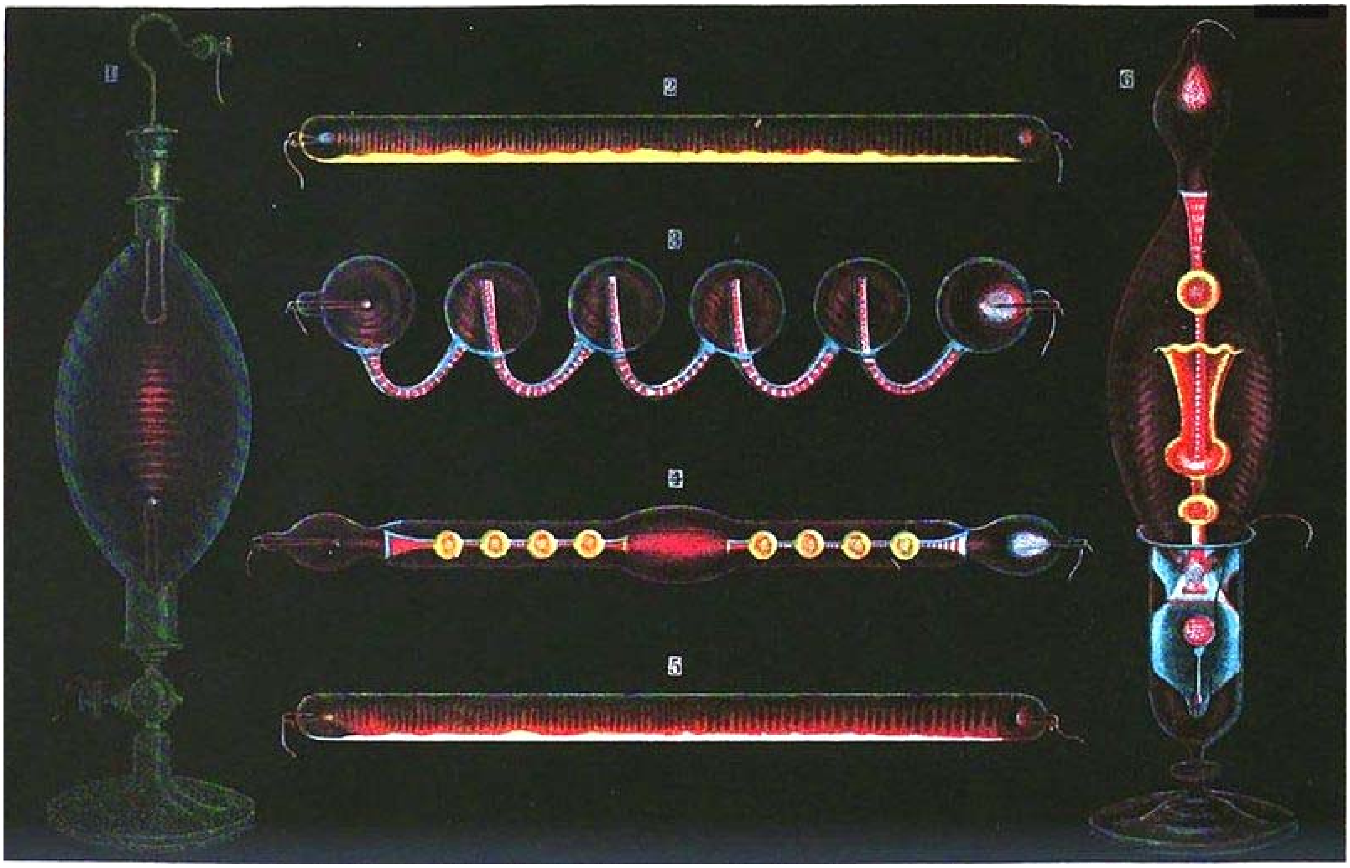
German physicist and inventor of the

Geissler tube,
a low pressure gas-discharge tube
made of glass.

These evacuated glass cylinder of various shapes, have two metal electrodes at either end. When a high voltage is applied between the electrodes, **electrons travel in straight lines from the cathode to the anode**. It was used by Crookes, Johann Hittorf, Juliusz Plücker, Eugen Goldstein, Heinrich Hertz, Philipp Lenard, J.J. Thomson, and others to discover the properties of cathode rays



Above: A diagram of Geissler's evacuated tube experiment.



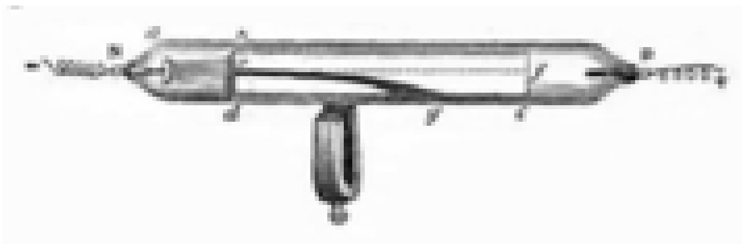
Above: Color drawing of Geissler tubes from an 1869 French physics book

William Crookes 1870's

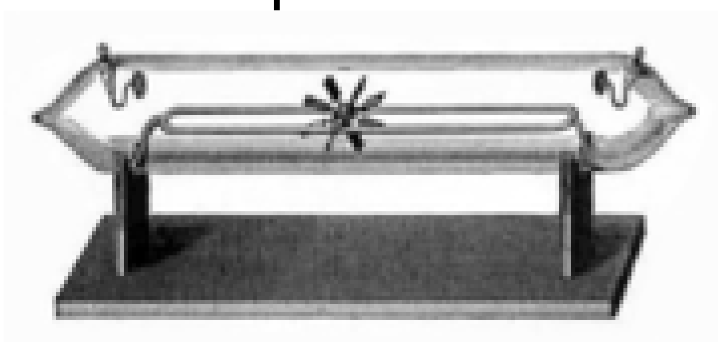
Above: A Crookes Tube casting a shadow at one end as the cathode rays are blocked by the metallic cross inside the tube.

During Crookes' investigations of the conduction of electricity in low pressure gases, he discovered that as the pressure was lowered, the negative electrode (cathode) appeared to emit rays (the so-called cathode rays, now known to be a stream of free electrons, and used in cathode ray display devices).

Crookes found that the cathode rays were deflected by magnets. This means that the "rays" must have an electric charge: positive(+) or negative(-)



Crookes also found that the cathode rays could exert a physical force on solid objects. His proof came from placing a paddle wheel inside the tube which turned when the cathode rays impacted it.



As these examples indicate, he was a pioneer in the construction and use of vacuum tubes for the study of physical phenomena.

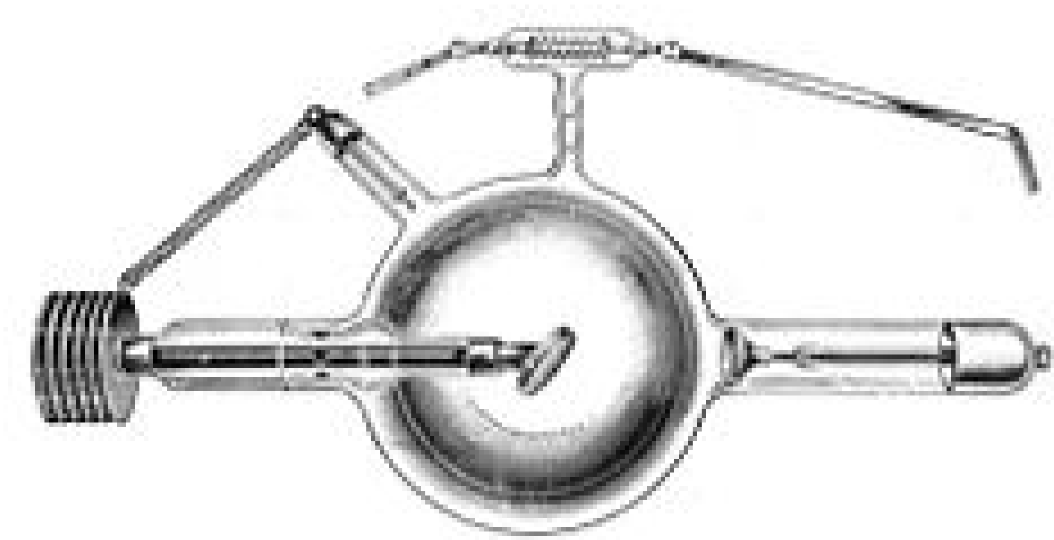
Discovery of x-rays

Wilhelm Röntgen 1895

Röntgen was investigating the external effects from the various types of vacuum tube equipment when an electrical discharge is passed through them. He was doing an experiment in which a thin aluminum window had been added to permit the cathode rays to exit the tube but a cardboard covering was added to protect the aluminum from damage by the strong electrostatic field that is necessary to produce the cathode rays. He knew the cardboard covering prevented light from escaping, yet Röntgen observed that the invisible cathode rays caused a fluorescent effect on a small cardboard screen painted with barium platinocyanide when it was placed close to the aluminum window. Röntgen speculated that a new kind of ray might be responsible. Nearly two weeks after his

discovery, he took the very first picture using x-rays of his wife's hand. When she saw her skeleton she exclaimed "I have seen my death!"

Left: Röntgen's first "medical" x-ray, of his wife's hand, taken on 22 December 1895



x-ray tube from around 1910.

When the voltage applied to a Crookes tube is high enough, around 5,000 volts or greater, it can accelerate the electrons to a fast enough velocity to create x-rays when they hit the anode or the glass wall of the tube.

Many early Crookes tubes undoubtedly generated x-rays, because early researchers noticed that they could make foggy marks on nearby unexposed photographic plates.

Röntgen received the first Nobel Prize in physics (1901) for his discovery of x-rays.

Discovery of Natural Radiation

1896

Antoine Henri Becquerel

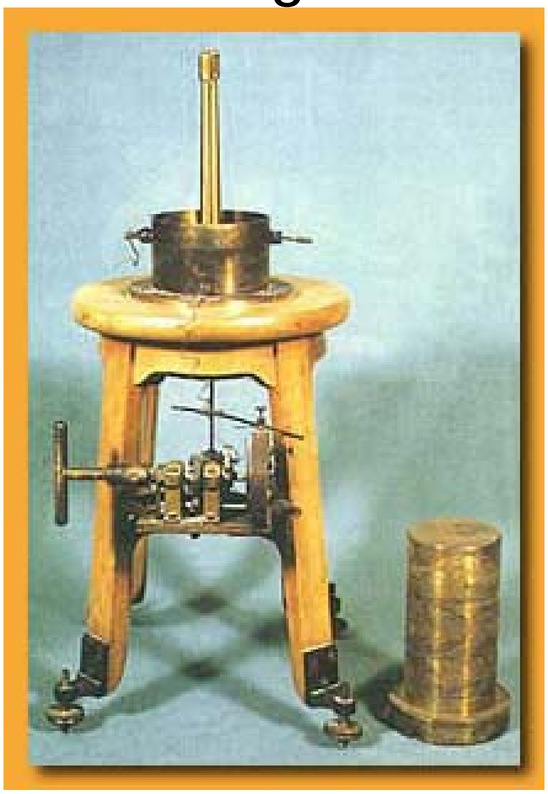
While investigating phosphorescence in uranium salts, Becquerel accidentally discovered radioactivity. Becquerel had wrapped a fluorescent substance, potassium uranyl sulfate, in photographic plates and black material in preparation for an experiment requiring bright sunlight. However, prior to actually performing the experiment, Becquerel found that the photographic plates were fully exposed. This discovery led Becquerel to investigate the spontaneous emission of nuclear radiation.

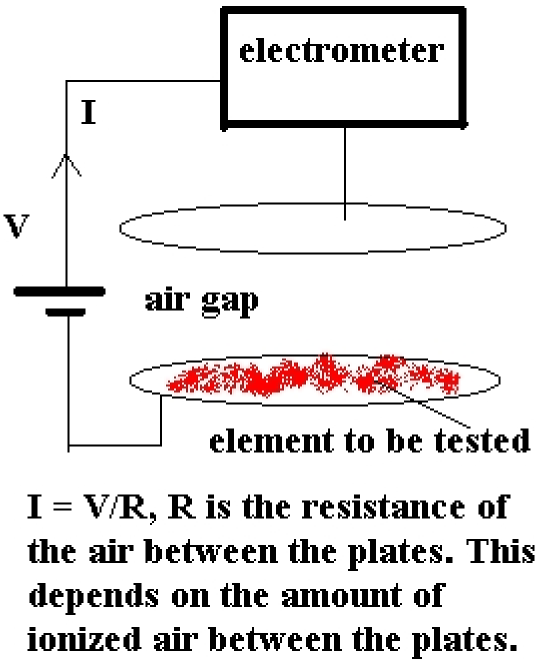
Above: Image of Becquerel's photographic plate which has been fogged by exposure to radiation from a uranium salt. The shadow of a metal Maltese Cross placed between the plate and the uranium salt is clearly visible.

In 1903, he shared the Nobel Prize in Physics with Pierre and Marie Curie "in recognition of the extraordinary services he has rendered by his discovery of spontaneous radioactivity".

1897 Marie Curie

Marie Curie decided to use the newly discovered "Becquerel Rays" as a field of research for a thesis. Fifteen years earlier, her husband and his brother had invented the electrometer, a device for measuring extremely low electrical currents.





Using the Curie electrometer, she discovered that uranium rays caused the air around a sample to conduct electricity. She showed that pitchblende, a uranium mineral, was four times as radioactive as uranium itself. She concluded that it must contain small amounts of some other substance far more radioactive than uranium.

With her husband's help and after a tremendous amount of laboratory work, she discovered the elements Polonium (Po) and Radium (Rn) in 1898.

Marie Curie coined the term "radiation" that came to replace the term "Becquerel Rays".

Marie Curie's death at age 66 was from aplastic anemia, was probably due to exposure to radiation. The damaging effects of ionizing radiation were then not yet known, and much of her work had been carried out in a shed without any safety measures. She had carried test tubes containing radioactive isotopes in her pocket and stored them in her desk drawer, remarking on the pretty blue-green light that the substances gave off in the dark.

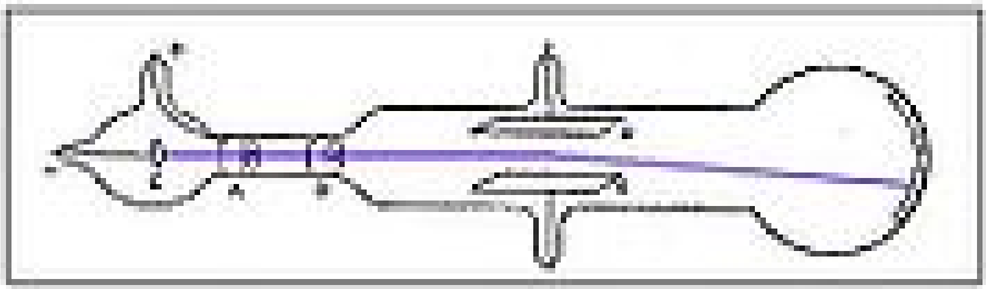
(Marie Curie received Nobel Prizes in both Chemistry and Physics.)

The electron – 1897

Sir Joseph John "J. J." Thomson

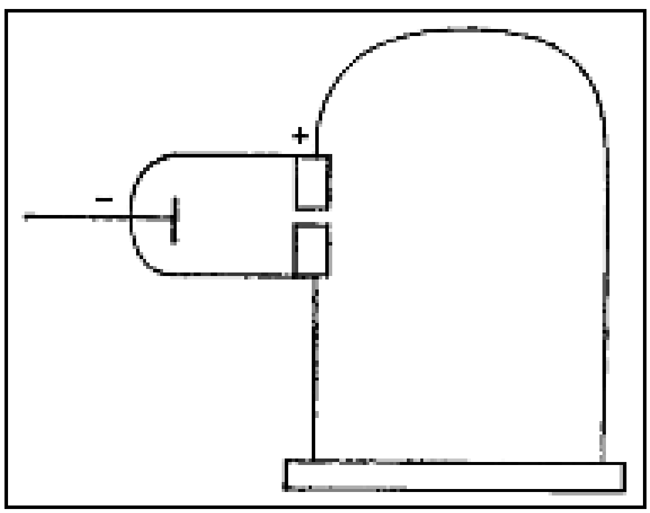
British physicist and Nobel laureate, credited for the discovery of the electron and of isotopes, and the invention of the mass spectrometer. He was awarded the 1906 Nobel Prize in Physics for the discovery of the electron and his work on the conduction of electricity in gases.

Thomson first investigated whether or not the negative charge could be separated from the cathode rays by means of magnetism.



Thomson constructed the cathode ray tube shown here, and found that the rays bent their path under the influence of an electric field, in a direction indicating a negative charge.

Then, Thomson measured the mass-to-charge ratio of the cathode rays by measuring how much they were deflected by a magnetic field and how much energy they carried.



He found that the mass to charge ratio was over a thousand times lower than that of a hydrogen ion (H^+), suggesting either that the particles were very light and/or very highly charged.

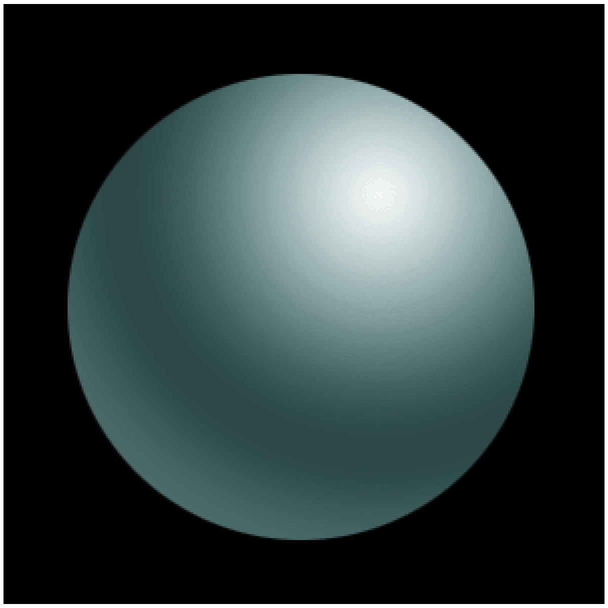
Thomson's conclusions were bold: cathode rays were indeed made of particles which he called "corpuscles", and these corpuscles came from within the atoms of the electrodes themselves, meaning that atoms are in fact divisible.

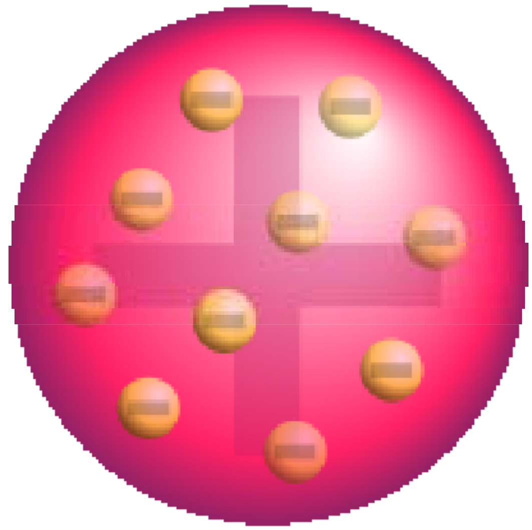
The "corpuscles" discovered by Thomson were eventually called electrons. The term “electron” had been already been in use a short time in the scientific community by the time Thomson published his discoveries.

By using different metals for the electrodes, Thomson showed that all electrons are the same no matter what element they come from.

The Atomic Theory Changes

Dalton's Atomic Theory → Thomson's Atomic Theory





Thomson imagined the atom as being made up of these corpuscles (electrons) swarming in a sea of positive charge; this was his plum pudding model.

Thomson's discovery was made known in 1897, and caused a sensation in scientific circles, eventually resulting in him being awarded a Nobel Prize in Physics in 1906.

The plum pudding model of the atom by J. J. Thomson, who discovered the electron in 1897, was proposed in 1904 before the discovery of the atomic nucleus.

How about the actual charge and mass of the electron?

1911 Robert Millikan

Starting in 1909, while a professor at the University of Chicago, Millikan worked on an oil-drop experiment which measured the charge on a single electron. Millikan went on to win the 1923 Nobel Prize for Physics

The Oil Drop Experiment