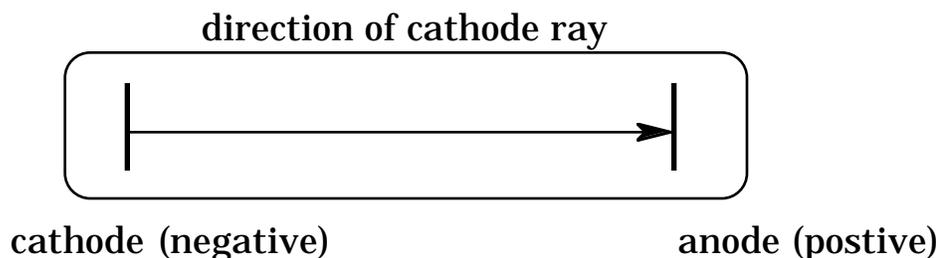


## J.J. Thomson Discovers the Proton

Remember that J.J. Thomson announced the discovery of the electron in 1897. This work culminated in about 1902.

### 1. The Production of Canal Rays

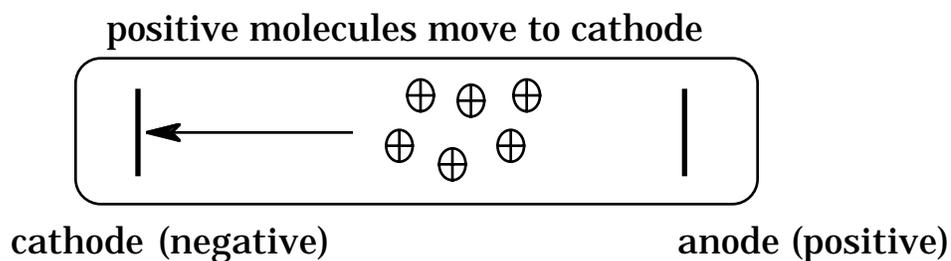
- a. Cathode rays are produced, which travel cathode to anode.



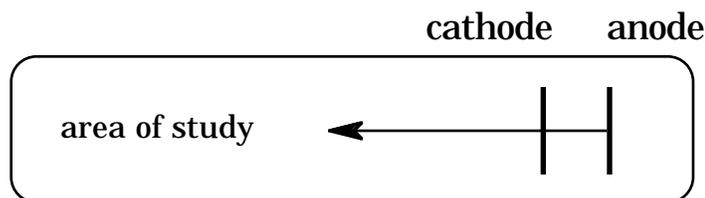
- b. Cathode rays (made of electrons) hit residual gas molecules between cathode and anode.

- c. Electrons are removed from the gas molecules by the impact. This makes the gas molecules positive in charge.

- d. The positively charged gas molecules are attracted to the negative cathode.



- e. Some slip through the holes in the cathode (the canals) and are studied. Note that the cathode and anode are placed close together.



the arrow shows the direction of the canal ray.

2. Both types of rays are produced in the two types of tube. The location and design of the cathode and anode determine if cathode rays or canal rays are studied.

3. Thomson determined the  $e/m$  ratio of the canal rays. He found that it varied depending on the type of gas that was present in the tube. There were also subtle variations within each value that led to the concept of isotopes. In other words, when hydrogen, chlorine, nitrogen, or neon was used, each had an  $e/m$  value different from the others. In the case of neon, as Thomson's equipment and technique became better, he noticed that neon gave two spots (very close to each other) at the same time. In other words, the same sample of neon was producing two slightly different  $e/m$  ratios.

4. The largest value obtained in these experiments was the  $e/m$  ratio for hydrogen. In 1898, W. Wein determined the  $e/m$  ratio for hydrogen in canal rays to be about  $10^4$ . This was consistent with the values from electrolysis.

5. The  $e/m$  ratio for hydrogen was known from electrolysis experiments dating to the 1830's. It was about  $10^5$ . Hydrogen had the largest  $e/m$  ratio when compared to other elements, because it was the lightest element. (Electrolysis - put anode and cathode in solution of chemicals. Turn on current. A chemical reaction takes place. From 1830's, it had been established by Faraday that a given amount of current ( $e$ ) would produce a given mass of chemical ( $m$ .)

6. Note that Thomson knew the  $e/m$  ratio for the electron to be  $1.76 \times 10^8$ . (This is expressed in the modern way. I think Thomson discussed it as the  $m/e$  ratio.) This meant that the electron must be much lighter than the hydrogen atom. A critical assumption (see #8 below) here was that hydrogen and the electron both had the same absolute amount of electrical charge, with hydrogen being positive and the electron negative.

7. Also, canal rays differed from cathode rays in another important respect. For example, helium had two possible  $e/m$  ratios, but not at the same time. At low voltage it had one ratio and at high voltage it had another ratio. It never showed both  $e/m$  ratios at the same time and it never switched values. It was always the same value at the low setting and always some other value at the higher setting. This was explained as follows. At low voltage one electron was released. At higher voltage, two electrons were released.

8. Hydrogen was the exception. It NEVER released more than one at any given voltage and therefore had ONLY one  $e/m$  ratio. This was explained as hydrogen having one electron, with one negative charge. And it had one positive charge (eventually called the proton).

9. Today the electron is known to be 1837 (p. 228 of Heath text) times lighter than the proton.