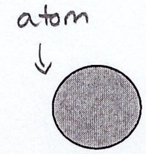
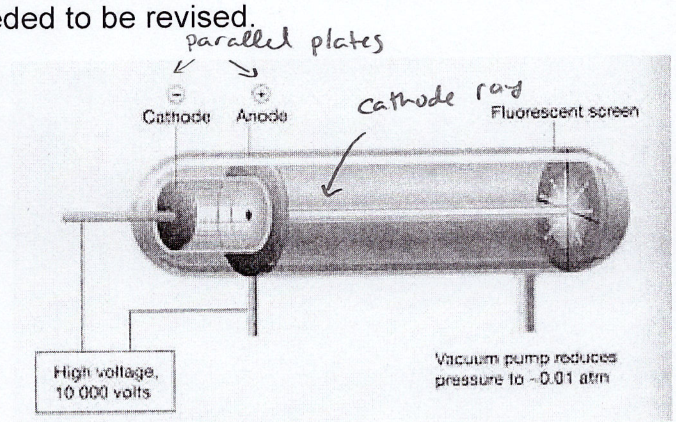
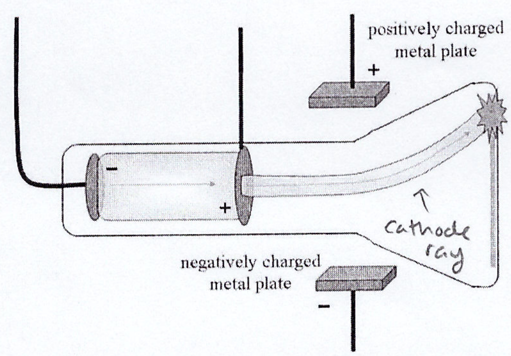
Development of the Atom



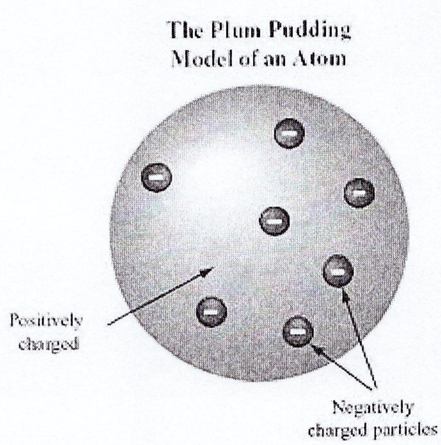
- Dalton was the first scientist who proposed a model for the atom. He suggested that an atom was a tiny, indivisible chucks of matter (ie. the billiard ball model)
- However, with the development of cathode ray tubes and the discovery of cathode rays, the model of the atom needed to be revised.
- A cathode ray tube consists of a set of parallel plates (electrodes) placed inside a glass tube that contains a gas under low pressure
    - When a voltage is applied across the parallel plates/electrodes, the gas in the tube will glow and a *cathode ray* will be emitted from one of the electrodes (ie. cathode)



- J.J. Thomson did a lot of his work with cathode ray tubes and observed some interesting properties of the cathode rays
    - travelled in straight lines
    - could be deflected by both magnetic and electrical fields (therefore, cathode rays **could not** be EMR)
    - It didn't matter what the cathode ray tube was made out of (ie. type of gas used or the type of metal used for the electrodes), the properties of the emitted cathode rays remained the same
- Thomson applied an external electric field (using a second set of parallel plates) and noticed that the rays would always bend towards the positively charged plate
    - * Thomson discovered that the cathode rays were actually tiny, negatively charged particles – the electron!



- With the discovery of the electron, Thomson revised the model of the atom to what was referred to as the "raisin-bun" or "plum pudding" model
    - Small, negatively charged particles (electrons) where embedded in a positively charged sphere
    - The atom now had components, instead of being an indivisible chuck

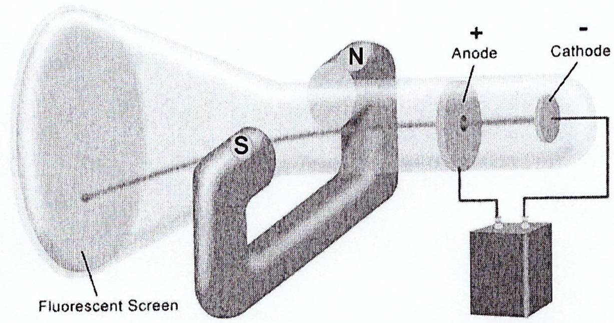


* Millikan discovered the elementary charge of e^-!

* Thomson continued to work with the cathode ray tubes to try and determine the <u>charge-to-mass</u> ratio of an electron
  - By applying an external magnetic field to the cathode rays travelling in a straight line, Thomson noticed the cathode rays bent in a circular path and he measured the radius of curvature

$$F_m = F_c$$
$$ma_c = qvB_\perp$$
$$m\left(\frac{v^2}{r}\right) = qvB_\perp$$
$$\frac{v}{B_\perp r} = q/m$$

charge-to-mass ratio



Cathode Ray Tube

explained by the 3rd left hand rule!

EXAMPLES

1. Charged particles are traveling horizontally at 3.60×10^6 m/s when they enter a vertical magnetic field of 0.710 T. If the radius of the arc of the deflected particles is 9.50×10^{-2} m, what is the charge to mass ratio of the particles?

$v = 3.60\times10^6$ m/s

$B_\perp = 0.710$ T

$r = 9.50\times10^{-2}$ m

$q/m = ?$

$$F_c = F_m$$
$$ma_c = qvB_\perp$$
$$m\left(\frac{v^2}{r}\right) = qvB_\perp$$
$$\frac{v}{rB_\perp} = q/m$$

$$q/m = \frac{(3.60\times10^6 \text{ m/s})}{(0.710\text{ T})(9.50\times10^{-2}\text{ m})} = 5.3372...\times10^7 \text{ C/kg}$$

$$\boxed{q/m = 5.34\times10^7 \text{ C/kg}}$$

2. What is the speed of an electron that passes through an electrical field of 6.30×10^{3} N/C and a magnetic field of 7.11×10^{-3} T un-deflected? Assume the magnetic field and electric field are perpendicular to each other.

$\vec{E} = 6.30\times10^{3}\,N/C$

$B_{\perp} = 7.11\times10^{-3}\,T$

$v = ?$

$F_{net} = 0.0\,N$

$\therefore\ F_e = F_m$

$q\vec{E} = qvB_{\perp}$

$\frac{\vec{E}}{B_{\perp}} = v$

$\frac{6.30\times10^{3}\,N/C}{7.11\times10^{-3}\,T} = v = 886075.94\ldots\,m/s$

$v = 8.86\times10^{5}\,m/s$

unit analysis

$\frac{N/C}{T} \times \left(\frac{T}{N/(C\cdot m/s)}\right) = \frac{1}{1/m\cdot s}$

$= m\cdot s$ ✓

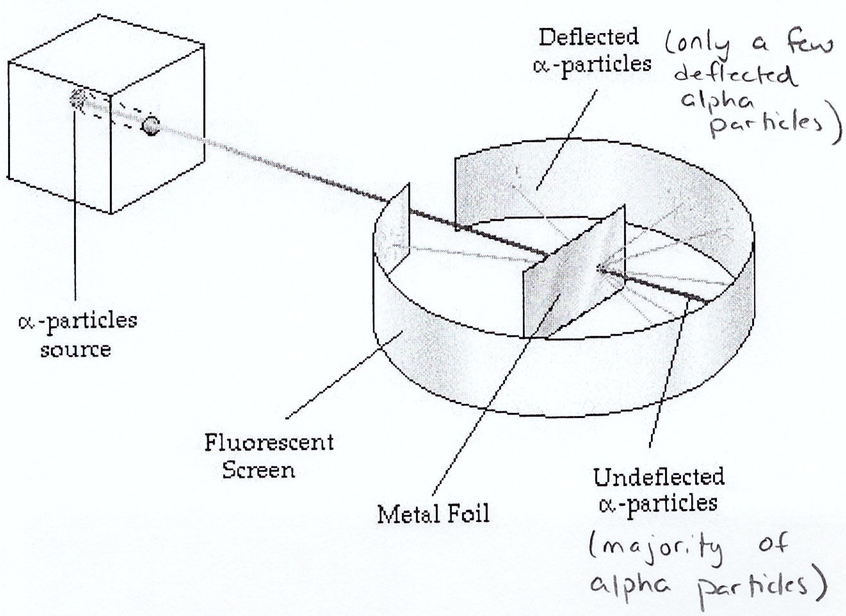
but $F_m = qvB$

$\therefore\ B = \frac{F_m}{qv} \Rightarrow T = \frac{N}{C\cdot m/s}$

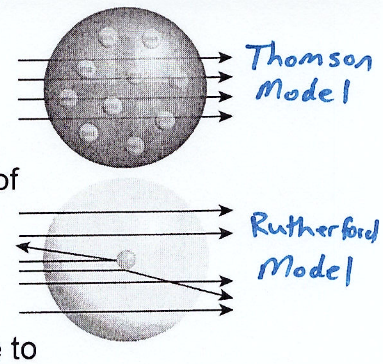
*****Now try pg. 286 #1, 2, 5-7*****

Rutherford's Scattering Experiment

- Alpha particles were directed toward a very thin gold foil
- Rutherford observed that although most of the alpha particles passed through the gold foil, a few were scattered at various angles
  - Some were even scattered back along their original path!
- This was like shooting bullets at a piece of tissue paper and finding some of them bounced back from the paper!



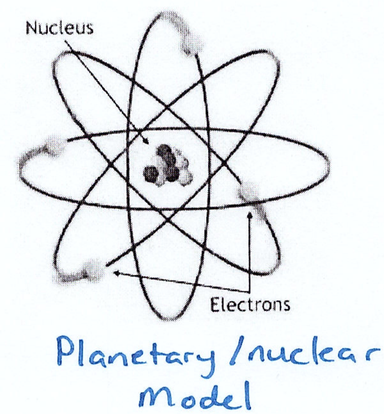
- Based off his observations, Rutherford concluded the mass of an atom is not evenly distributed throughout the atom as proposed by Thomson and his raisin bun model, but instead the bulk of the mass (the positive part of the atom) is concentrated in a very small region of the atom (ie. called the nucleus). The bulk volume of an atom consists of the electrons (small and not much mass).
  - This explained why most of the alpha particles passed through un-deflected because the electrons would not be able to deflect the larger alpha particles. However, the more massive, but small volume center, would cause only some alpha particles to be deflected by collision or electrostatic repulsion.

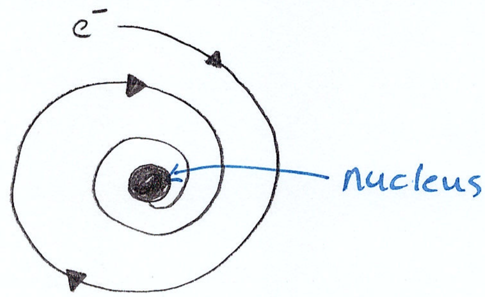


- But there was a flaw to Rutherford's model. If the positive nucleus is concentrated in the center of the atom, what keeps the electrons from being pulled into the nucleus due to electrostatic attraction and resulting in the atom collapsing?

- The *planetary/nuclear model* of the atom was then proposed and explained that if the electrons where orbiting the nucleus (like planets orbit the sun) the electrons would stay in a circular orbit (e^- moving in a circular path)
  - But an accelerating charged particle will emit EMR and if the electron is emitting energy, it will lose kinetic energy and spiral into the nucleus!

∴ collapsing the atom





- The model of the atom had come along way since Dalton, but with the catastrophic flaws with the planetary/nuclear model, the model of the atom still needed revision

*****Now try pg. 288 #8-9 & Practice Problems*****

Practice Problems

1. Explain how the results from Rutherford's gold-foil experiment disproved Thomson's model of the atom.
2. Briefly describe the planetary model of the atom.
3. Why does the scattering angle increase as alpha particles pass closer to the nucleus?
4. Why did Rutherford conclude that it was just the nucleus that must be extremely tiny in an atom and not the entire atom?

Solutions

1. The fact that *some* alpha particles were deflected at large angles when fired at a piece of thin gold foil meant that the bulk of the mass and positive charge was concentrated at the center of the atom. If Thomson's model of the atom was correct, *none* of the alpha particles would have been deflected at large angles because the negative and positive charges were evenly distributed among the atom and you wouldn't get a large electrostatic repulsion to deflect the alpha particles.
2. The planetary model of the atom was just an extension to Rutherford's model that stated the mass of the atom was concentrated at the center. The planetary model went one step further and stated that the electrons were in constant motion/orbit around the nucleus, just like planets orbit the sun. The force centripetal would be equal to the electrical force of attraction between the electrons and the positive nucleus, therefore keeping the electrons in orbit just like how the planets stay in orbit around the sun.
3. As the distance between the alpha particle (+) and the nucleus (+) become smaller, the electrical force of repulsion becomes larger due to the formula $F_e = \frac{kq_1q_2}{r^2}$. A larger force of repulsion between similar charges will result in a larger deflection.
4. The fact that *most* of the alpha particles went through un-deflected meant that only a small part of the atom was massive and positive.