ATOMIC STRUCTURE

1. The Nuclear Atom
2. Electron Orbits
3. Atomic Spectra
4. The Bohr Atom
5. Energy Level and Spectra
6. Correspondence Principle
7. Nuclear Motion
8. Atomic Excitation
9. The Laser

INTRODUCTION

In 1913, Niels Bohr applied quantum ideas to atomic structure. It was later replaced by a more accurate model but it is still remains convenient mental picture of the atom.

Bohr's theory of the hydrogen atom is valuable because it provides a transition to the more abstract quantum theory of the atom.

THE NUCLEAR ATOM

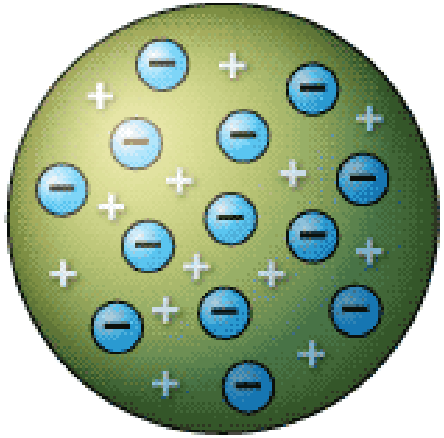
In the late 19^{th} century, most scientists accepted the idea that the chemical elements consists of atoms but didn't know anything about them.

One discovery that all atoms contain electrons and since electrons have negative charge whereas atoms are neutral, then positively charged matter must be present in atoms.

How are these negative and positive charges arranged?

THE NUCLEAR ATOM

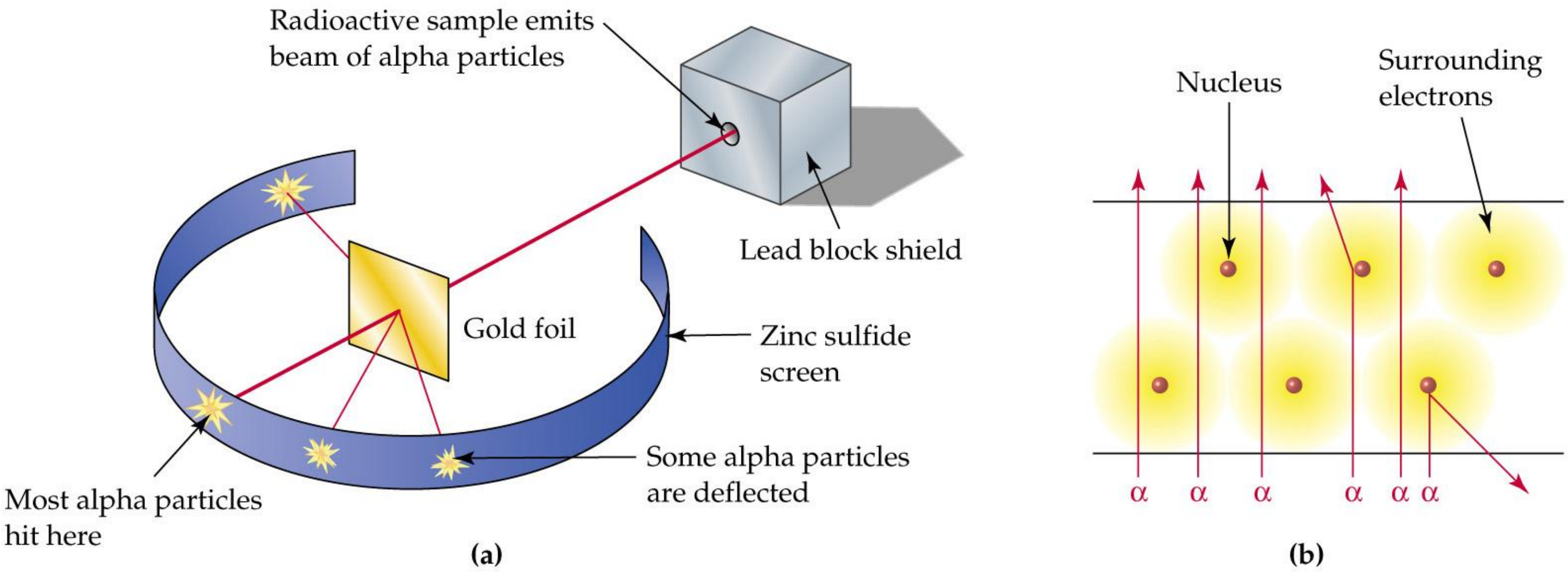
In 1898, J. J. Thomson suggested that atoms are positive charge lumps of matter with electrons embedded in them. (plume pudding model)



How can we know if this is a correct model or not?

THE NUCLEAR ATOM

Geiger and Marsden at the suggestion of Rutherford used fast **alpha particles (He^{+2})** as probes emitted by certain radioactive elements.



What was expected based on Thomson model?

THE NUCLEAR ATOM

What was found:

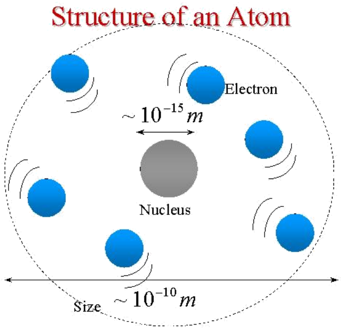
1. Most alpha particles were not deviated by much.
2. Few alpha particles were scattered through very large angles.
3. Some particles were scattered in the backward direction.

"it was as incredible as if you fired a 15-in shell at a piece of tissue paper and it came back to him you" – Rutherford.

THE NUCLEAR ATOM

Rutherford's explanation:

1. Atoms are composed of tiny nucleus in which its positive charge and nearly all its mass are concentrated, with the electrons some distance away.
2. Atoms are largely empty space so alpha particles go right through a thin foil but when they come near the nucleus an intense electric field scatter it through an angle.
3. Atomic electrons are light so do not affect the alpha particles.



Using various target materials, Geiger and Marsden managed to find the nuclear charge of the atoms.

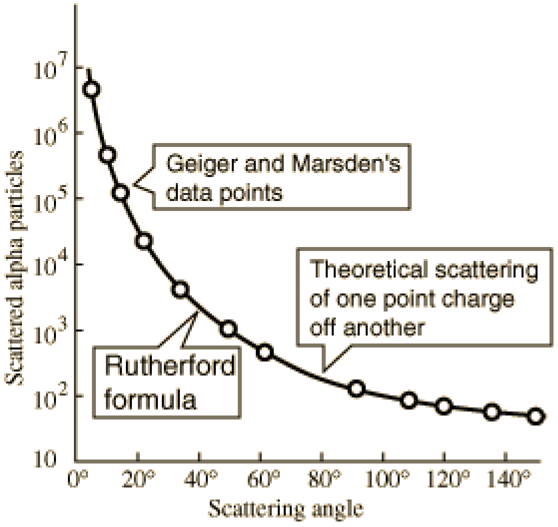
Nuclear charge is multiple of +e; Z number of units is known as atomic number of the element.

THE NUCLEAR ATOM

Rutherford Scattering Formula:

$$N(\theta) = \frac{N_i n t Z^2 e^4}{(8\pi\varepsilon_o)^2 r^2 KE^2 \sin^4(\theta/2)}$$

$N(\theta)$= number of alpha particles per unit area that reach the screen at a scattering angle of θ.
N_i= total number of alpha particles that reach the screen.
n = number of atoms per unit volume in the foil.
Z = atomic number of the foil atoms.
r = distance of the screen from the foil.
KE = kinetic energy of the alpha particles.
t = foil thickness.



THE NUCLEAR ATOM

Nuclear Dimensions

Rutherford scattering can be a way to find the upper limit of nuclear dimensions by calculating the distance of closest approach.

$$KE_{initial} = PE = \frac{1}{4\pi\varepsilon_o}\frac{2Ze^2}{R}$$

Since the charge of the alpha particle is 2e and that of the nucleus Ze, then:

$$R = \frac{1}{4\pi\varepsilon_o}\frac{2Ze^2}{KE_{initial}}$$

THE NUCLEAR ATOM

Nuclear Dimensions

The maximum KE found in alpha particles of natural origin is 7.7 MeV (= 1.2×10^{-12} J) and $1/4\pi\varepsilon_o = 9 \times 10^9$ N.m²/C²

Then...

$$R = \frac{1}{4\pi\varepsilon_o}\frac{2Ze^2}{KE_{initial}} = \frac{(2)(9\times10^9\,N.m^2/C^2)(1.6\times10^{-19}C)^2}{1.2\times10^{-12}J} = 3.8\times10^{-16}Z\ m$$

For gold: Z = 79

R(Au) = 3×10^{-14} m

Rutherford prediction is a good approximation but failed when using particles of higher energy.

THE NUCLEAR ATOM

Remember…

An atom is largely empty space.