Models of the atom.

Thomson model :

sphere of positive charge with electrons embedded

Features: 1). Ground state has electrons fixed at equilibrium positions

2). ~~excited~~ states have electrons vibrating around equilibrium positions

3). electron vibration ⇒ emission

note : $\begin{cases} \text{qualitative ok} \\ \text{quantitative not ok} \end{cases}$ ⇒ kills the model.

Rutherford model :

based on α scattering of ~~[illegible]~~ atoms

observed large deflections with finite probability

Facts : since $m_e \ll m_\alpha$ deflections due to scatterings of electrons is small

Large deflections require strong Coulomb repulsion. Can not be provided if + charge is distributed over 10^{-10} m.

If large deflections are due to multiple scatterings we can determine the fraction of backwards going α particles : 10^{-3500}
Observed value is 10^{-4}

⇒ Thomson + multiple scattering fails.

⇒ Assume α's backscattered due to a single scatter ⇒ require + charge to be concentrated in small volume (10^{-14} m).

Rutherford developed a model to describe the observed scattering distributions.

1). incident α particles have a specific impact parameter. (b).
2). there is a one-to-one correlation between impact parameter and
   - scattering angle θ
   - distance of closest approach R.
3). Smallest value of R in a head-on collision. ($R_{min} = D$).

Results:

$$\frac{N(\theta)\,d\theta}{I} = \frac{\pi}{8}\,\rho\, t\, D^2\, \frac{\sin\theta\, d\theta}{\sin^4(\theta/2)}$$

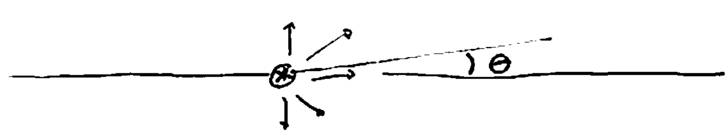
ρ: density of nuclei in $\#/cm^3$

t: Thickness foil (cm)

$$D = \frac{1}{4\pi\varepsilon_0}\,\frac{zZe^2}{(\frac{1}{2}Mv^2)}$$ = dist. of closest approach in head-on collision.

Experiment :

- fixed cross section of detector will capture different fractions of particles at different angles
- measured rates must be normalized for this type of variations
- Consider random emission :



reference axis

# of particle emitted with $\theta = 0°$ will be very small (same for $180°$)

# of particles emitted with $\theta = 90°$ will be very large

$\Rightarrow$ angle dependent probability.

⊛ remove trivial θ dependence

$$d\Omega = \frac{\text{area}}{r^2} = 2\pi \sin\theta \, d\theta$$

⊛ measured values are converted to

$$\frac{d\sigma}{d\Omega} = \frac{dN}{In} \cdot \frac{1}{d\Omega} = \frac{N d\theta}{In} \cdot \frac{1}{d\Omega} = \left(\frac{1}{4\pi\varepsilon_0}\right)^2 \left(\frac{zZe^2}{2Mv^2}\right)^2 \frac{1}{\sin^4(\theta/2)}$$

$$\sqrt{8\left(\tfrac{1}{2}\right)^2 \cdot 2}$$

⊛ deviation of $\left(\frac{d\sigma}{d\Omega}\right)_{Ruth}$ as function of distance can be used to determine the size of the nucleus. If $D < R_{nucleus}$ $\Rightarrow$ nuclear force becomes important $\Rightarrow$ no pure Rutherford scattering.

Atomic spectra:

* wave lengths emitted are discrete.

* hydrogen spectrum is simple.
  empirical formula:

$$\text{Balmer:} \quad \lambda = 3646 \, \frac{n^2}{n^2 - 4}$$

$$k = \frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$$

R_H → Rydberg constant for H

Similar formula were found for other series.

Bohr atoms:

note: mixture of classical and non-classical physics.

Bohr made the following assumptions:

* electrons move in circular orbits
* $L_{orbit} = n\hbar$ (only certain orbits are allowed).
* orbits are stable – no radiated energy
* radiation emitted when transitions occur between energy levels.

Classical physics is used to determine energy of electrons :

$$E = - \frac{m_e Z^2 e^4}{(4\pi\varepsilon_0)^2 (2\hbar^2)} \frac{1}{n^2} \qquad n = 1, 2, 3, \ldots$$

Energy < 0. Unbound electron if $E \geq 0$

Note : predictions agree very well with exp. values.

→ model predicted lines that were not observed yet, but later confirmed to exist.

Note : precise measurements show that a correction must be made for the nuclear mass. Instead of using m_e we use the reduced mass μ where

$$\mu = \frac{mM}{m + M}$$

Rydberg constant changes by 1 part in 2000 for Hydrogen (biggest change).

Bohr predictions agree with data within 3 parts of 100,000. Amazing!

Confirmation of energy states in atoms obtained by Franck and Hertz.

- accelerate electrons
- measure current
- observe significant dips:

  in Hg first dip at 4.5 V ⇒ loose a lot of electrons

  What happens:

  4.5 eV e^- interacts with atom and excites it

  ↳ e^- now has energy to low to be collected

  ↳ excited atom emits a 4.5 eV γ.