Announcements

- Homework 6 is due March 10, this Friday.
- Homework 7 is due March 22, the Wednesday after the spring break.
- Prof. Tanner’s office hour today is over zoom, no office hour this Friday.

Today's class

- Rutherford scattering

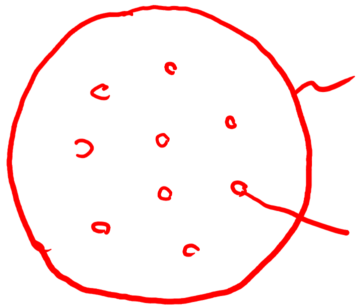
Atoms

All matter is composed of individual atoms

atoms → uncuttable

→ neutral in charge (electrons ⊖, positive charge)

JJ Thompson model for atoms



$+Ze$ homogeneous ⊕

electrons ⊖ evenly distributed

"plum pudding"

Introducing today’s Nobel laureate

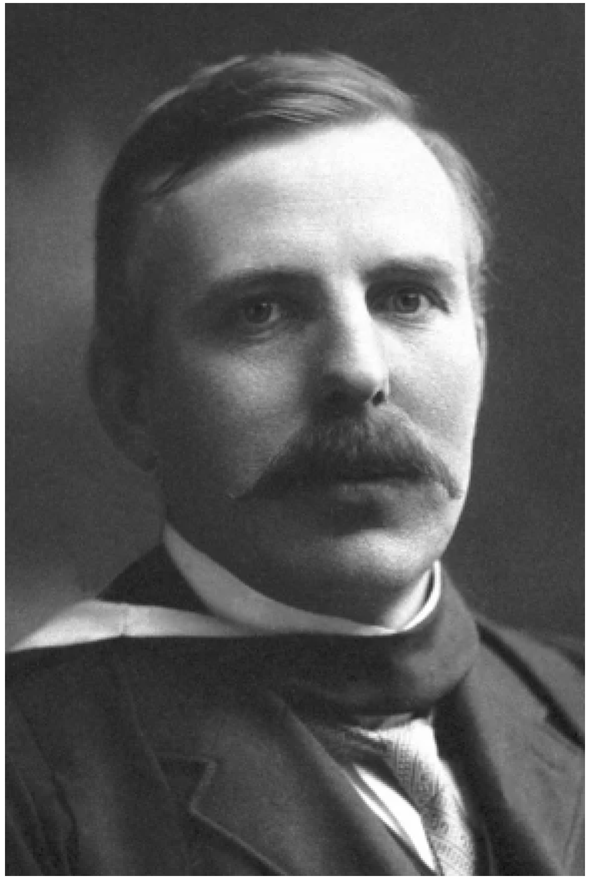


Photo from the Nobel Foundation archive.

Ernest Rutherford
The Nobel Prize in Chemistry 1908

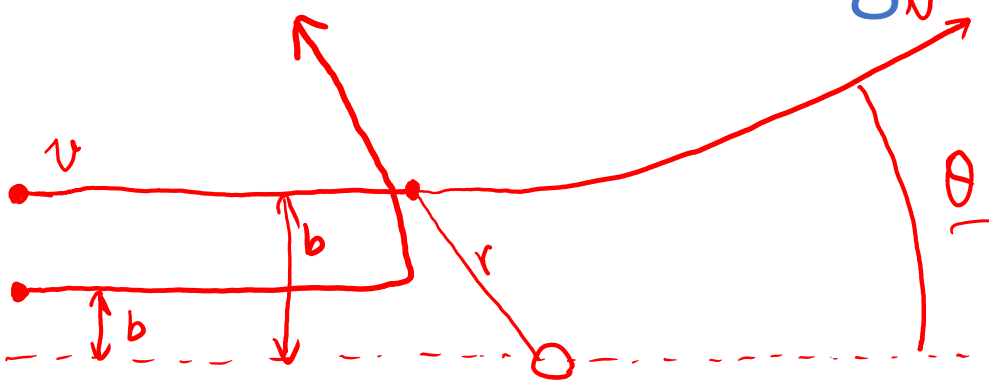
Born: 30 August 1871, Nelson, New Zealand

Died: 19 October 1937, Cambridge, United Kingdom

Affiliation at the time of the award: Victoria University, Manchester, United Kingdom

Prize motivation: “for his investigations into the disintegration of the elements, and the chemistry of radioactive substances”

Rutherford scattering



$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{zZe^2}{r^2}$$

$$K = \frac{1}{2} m_\alpha v^2$$

θ : deflection angle

$$b = \frac{zZe^2}{8\pi\varepsilon_0 K} \cot\frac{\theta}{2}$$

$$\boxed{b = \frac{zZ}{2K} \cdot \frac{e^2}{4\pi\varepsilon_0} \cdot \cot\frac{\theta}{2}}$$

heavy atom nucleus $+Ze$

• α particle He^{2+} $z = 2$. $m_\alpha = 4$

b: impact parameter

$b\uparrow$ $\theta\downarrow$

$b\downarrow$ $\theta\uparrow$

$z = 2$ atomic # for α particle

Z . . . . . for heavy atom.

"head on" collision $b = 0$, $\theta = 180°$

e : elemental charge

ε_0 : vacuum permissivity

$$\frac{e^2}{4\pi\varepsilon_0} = 1.44\,\text{eV}\cdot\text{nm} = 1.44\,\text{MeV}\cdot\text{fm}$$

initially, K.E. of α

↓

decreased K.E of α + increased potential energy

↓

finally, regain K.E. of α

In-class exercise (5 min)

An alpha particle with a kinetic energy of 5.0 MeV is scattered on a Al (Z=13) foil. Find the closest distance the alpha particle can possibly approach the Al nucleus.

$K = 5.0\,MeV$ $\quad$ $\alpha, +2e$ $\quad$ Al, +13e $\quad$ $b = 0$ $\quad$ $\theta = 180^\circ$

energy is conserved.

$$E_i = K = \frac{1}{2} m_\alpha v^2$$

$$E_f = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_\alpha q_N}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2 \cdot 13\, e^2}{r}$$

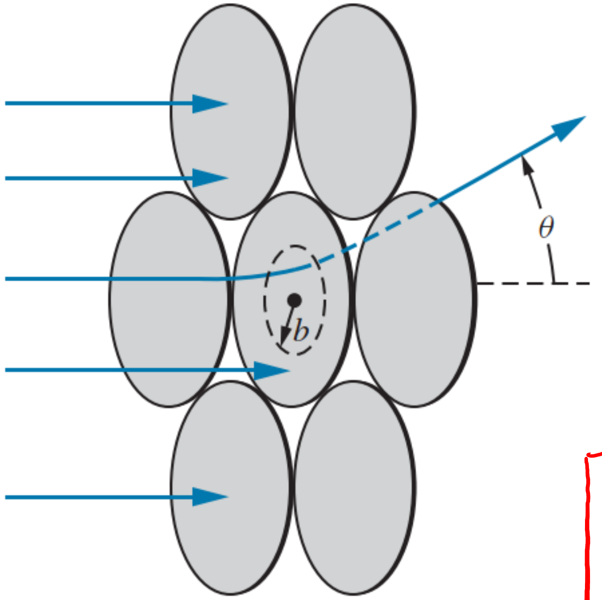
$$E_i = E_f \Rightarrow K = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2 \cdot 13\, e^2}{r}$$

$$r = \frac{e^2}{4\pi\varepsilon_0} \cdot \frac{2 \cdot 13}{K} = 1.44\,MeV \cdot fm \cdot \frac{2 \cdot 13}{5.0\,MeV} = 7.5\,fm$$

$fm = 10^{-15}\,m$

atom dimension : $1\,\text{Å} = 10^{-10}\,m$

Rutherford scattering through multi-layer atoms



single-layer

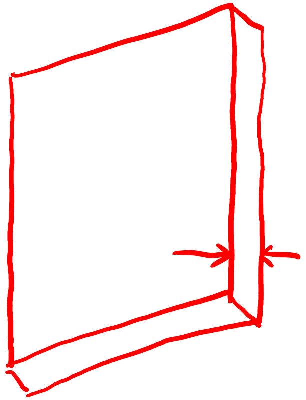
$b \longleftrightarrow \theta$

fraction of α with a deflection angle $> \theta$, $f_{>\theta}$

$$f_{<b} = f_{>\theta} = \frac{\pi b^2}{\pi R^2}$$

R is the radius of the atoms

multi-layer (real scattering)



For a given material, we know ρ, M

$$\#\text{ of atoms} = N_A \frac{\rho \cdot V}{M}$$

N_A : avogadro #

$$f_{<b} = f_{>\theta} = \frac{N_A \frac{\rho V}{M} \cdot \pi b^2}{A} = N_A \frac{\rho}{M} t \pi b^2$$

If a questions asks for $f_{>\theta}$. $\theta \longleftrightarrow b$