Announcements

- Homework 6 is due March 10, this Friday.
- Homework 7 is due March 22, the Wednesday after the spring break.

Last time

- Rutherford scattering

Today’s class

- Bohr model

in-class quiz (5 min)

Alpha particles of kinetic energy 5.0 MeV are scattered onto an Al foil (ρ = 2.7 g/cm^3, M = 27 g/mole) with a thickness of 1.0×10^{-6}m. Find the fraction of the alpha particles scattered at angles greater than 90º.

A. 2.6×10^{-3}

B. 2.6×10^{-4}

C. 2.6×10^{-5}

D. 2.6×10^{-6}

E. 2.6×10^{-9}

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Alpha particles of kinetic energy 5.0 MeV are scattered onto an Al foil (ρ = 2.7 g/cm^3, M = 27 g/mole) with a thickness of 1.0×10^{-6}m. Find the fraction of the alpha particles scattered at angles greater than 90º.

$$b = \frac{zZ}{2K} \cdot \frac{e^2}{4\pi\varepsilon_0} \cot\frac{\theta}{2} = \frac{2 \cdot 13}{2 \cdot 5.0\,\text{MeV}} \cdot 1.44\,\text{MeV} \cdot \text{fm} \cdot \underbrace{\cot 45^\circ}_{1} = 3.7\,\text{fm}$$

$$f_{>90^\circ} = N_A \cdot \frac{\rho}{M} \cdot t \cdot \pi b^2 = 6.02\times10^{23}/\text{mole} \cdot \frac{2.7\times10^3\,\text{kg/m}^3}{27\times10^{-3}\,\text{kg/mole}} \cdot 1.0\times10^{-6}\,\text{m} \cdot 3.14 \cdot (3.7\cdot10^{-15}\,\text{m})^2$$

$$= 2.6\times10^{-6}$$

A. 2.6 ×10^{-3}

B. 2.6 ×10^{-4}

C. 2.6 ×10^{-5}

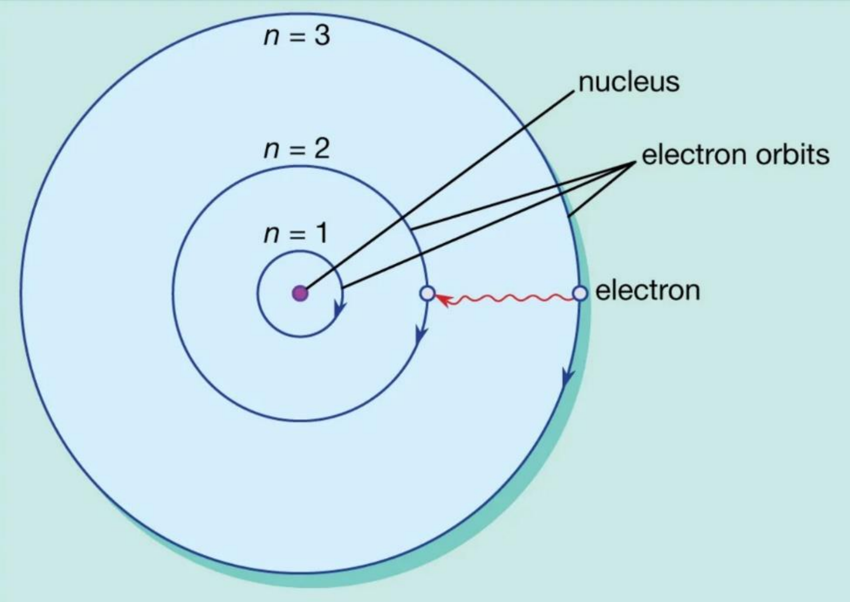
D. 2.6 ×10^{-6}

E. 2.6 ×10^{-9}

Introducing today's Nobel laureate

The Nobel Prize in Physics 1922 was awarded to Niels Henrik David Bohr "for his services in the **investigation of the structure of atoms** and of the radiation emanating from them"

Bohr model



$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r^2} = m\frac{v^2}{r}$$

$$v^2 = \frac{e^2}{4\pi\varepsilon_0}\cdot\frac{Z}{mr}, \quad v = \sqrt{\frac{e^2}{4\pi\varepsilon_0}\cdot\frac{Z}{mr}}$$

period $T = \frac{2\pi r}{v} = \frac{2\pi r}{\sqrt{\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{mr}}} = \sqrt{\frac{4\pi^2 r^2 \cdot 4\pi\varepsilon_0 m r}{Ze^2}} = \sqrt{\frac{16\pi^3\varepsilon_0 m r^3}{Ze^2}}$

$$f = \frac{1}{T} = \sqrt{\frac{Ze^2}{16\pi^3\varepsilon_0 m r^3}}$$

total Energy $E = K + U$

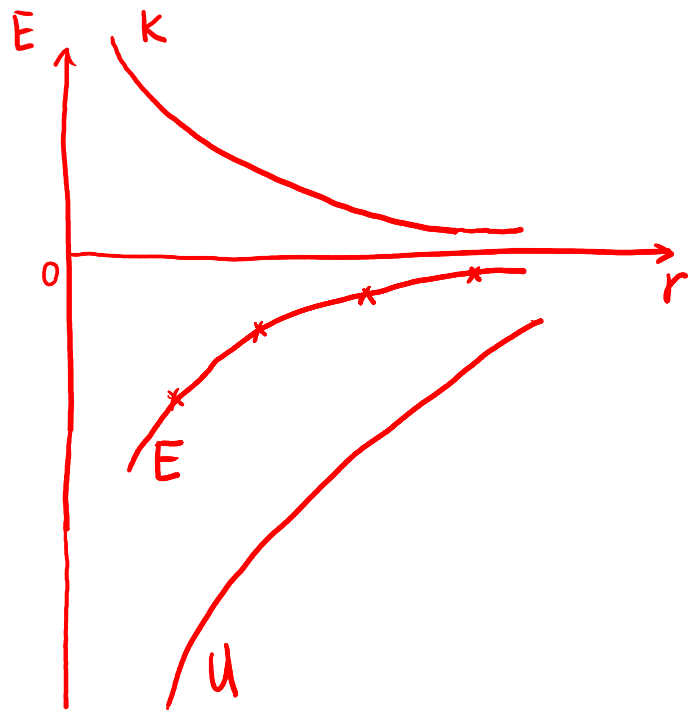
nucleus heavy. $m_N \to \infty$, $K_N \to 0$

Kinetic energy $K = \frac{1}{2}mv^2 = \frac{1}{2}\cdot\frac{e^2}{4\pi\varepsilon_0}\frac{Z}{r}$

potential energy $U = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r} = -\frac{e^2}{4\pi\varepsilon_0}\frac{Z}{r}$

$U \to 0 \quad r \to \infty$

$$E = K + U = \frac{1}{2}\cdot\frac{e^2}{4\pi\varepsilon_0}\frac{Z}{r} - \frac{e^2}{4\pi\varepsilon_0}\cdot\frac{Z}{r} = -\frac{1}{2}\cdot\frac{e^2}{4\pi\varepsilon_0}\cdot\frac{Z}{r} = -\frac{Ze^2}{8\pi\varepsilon_0 r}$$



$$K = \frac{1}{2} \cdot \frac{e^2}{4\pi\varepsilon_0} \frac{Z}{r} \sim \frac{1}{r}$$

$$U = -\frac{e^2}{4\pi\varepsilon_0} \frac{Z}{r} \sim -\frac{1}{r} \quad , \quad |U| = 2K$$

$$E = -\frac{e^2}{8\pi\varepsilon_0} \frac{Z}{r} \sim -\frac{1}{r} , \quad |E| = K$$

Bohr's Postulate

Bohr's assumption is quantization of angular momentum.

$L = n\hbar \qquad n = 1, 2, 3, \cdots$ analogous to quantized energy $E = nhf$

$L = rp = mvr$

$$\boxed{n\hbar = mvr}$$

$$L_n = n\hbar = mvr = m\sqrt{\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{mr_n}} \cdot r_n$$

$$v = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{mr}}$$

$$n^2\hbar^2 = m^2 \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2}{mr_n} \cdot r_n^2 = m \cdot \frac{1}{4\pi\varepsilon_0} \cdot Ze^2 \cdot r_n$$

$$r_n = \frac{n^2\hbar^2}{m} \cdot \frac{4\pi\varepsilon_0}{Ze^2} = \frac{n^2}{Z} \cdot \frac{\hbar^2 \cdot 4\pi\varepsilon_0}{me^2} = \frac{n^2}{Z} a_0$$

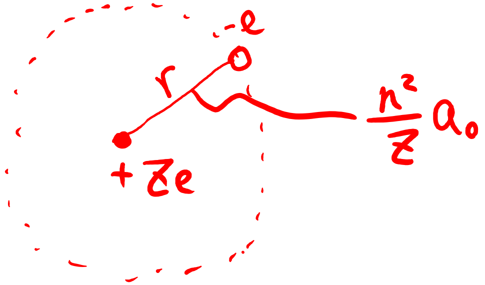
a_0 Bohr radius

$$= \frac{\hbar^2}{me^2} 4\pi\varepsilon_0$$

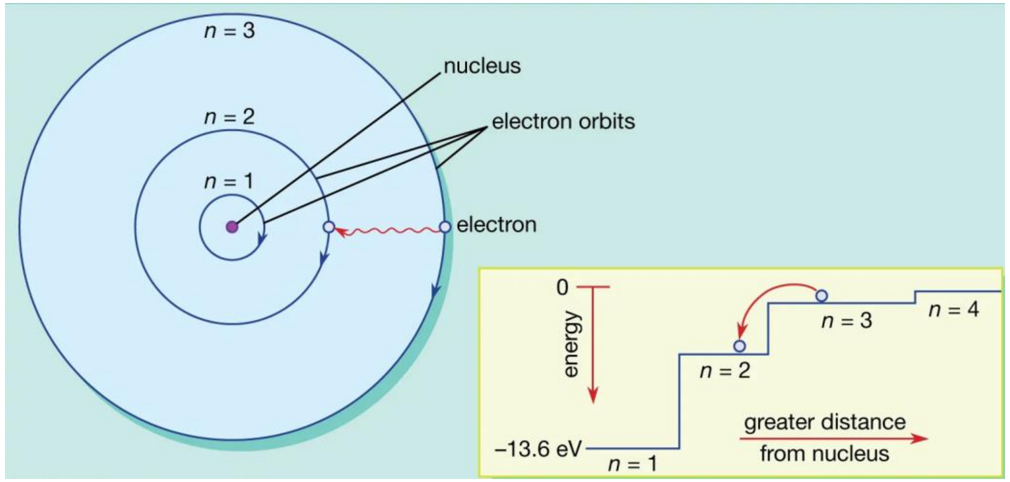
$$= 0.0529\,\text{nm}$$

$$= 52.9\,\text{pm} \longrightarrow 2a_0 \text{ size}$$

near Å dimension



Bohr model



$$E = -\frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r}$$

$$E_n = -\frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

$$= -\frac{Ze^2}{8\pi\varepsilon_0}\cdot\frac{m}{n^2\hbar^2}\cdot\frac{Ze^2}{4\pi\varepsilon_0} = -\frac{Z^2e^4m}{32\pi^2\varepsilon_0^2\hbar^2}\cdot\frac{1}{n^2}$$

$$= -\frac{Z^2}{n^2}\cdot\underbrace{\frac{e^4m}{32\pi^2\varepsilon_0^2\hbar^2}}$$

$$= -\frac{Z^2}{n^2}R_y \qquad R_y \equiv \frac{e^4m}{32\pi^2\varepsilon_0^2\hbar^2} = 13.6\,\text{eV}$$

Rydberg unit of energy: binding energy btw a single electron and a proton.

Rydberg wavelength: inverse wavelength of the photon created at this binding energy

$$R_y = \Delta E = \frac{hc}{\lambda}$$

$$13.6\,\text{eV} = 1240\,\text{eV}\cdot\text{nm}\cdot\frac{1}{\lambda}$$

$$\frac{13.6}{1240\,\text{nm}} = \frac{1}{\lambda}$$

$$= 0.0109\times10^{9}\,\text{m}^{-1}$$

$$= 1.09\times10^{7}\,\text{m}^{-1}$$