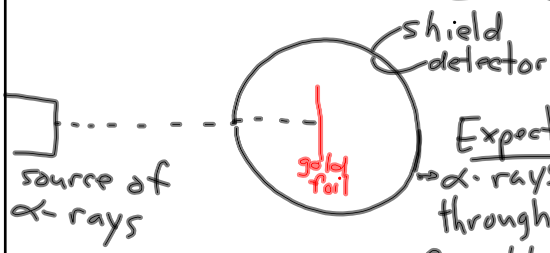
# The Atom

## Rutherford's Gold Foil Exp.:




**Expected:**
→ α-rays go through foil

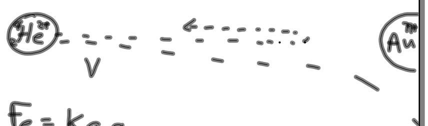
**Results**
- ~99% did go through
- ~1% slight deflection
- a few reflected straight back!

∴ "Raisin-bun" model is wrong

**Conclusion:**
- must have a very dense, very small, positive area in the atom
→ the nucleus

↳ later: nucleus composed of protons & neutrons

The physics of Rutherford's experiment:




$F_e = \frac{Kq_1q_2}{r^2}$

Also $E_e = \frac{Kq_1q_2}{r}$

Ex. How close will an α-particle get to the centre of a Au nucleus if the ~~nucleus~~ α-particle is moving at $1\times10^6\ \frac{m}{s}$?


$E_i = E_K$ $\qquad E_f = E_e$

$\therefore E_K = E_e$

$\frac{1}{2}mv^2 = \frac{Kq_1q_2}{r}$

$m_\alpha = 4u$
$= 4(1.67\times10^{-27})$
$= 6.668\times10^{-27}$ kg

$q_1 = 2+$
$= 2(1.602\times10^{-19}\ C)$
$= 3.204\times10^{-19}\ C$

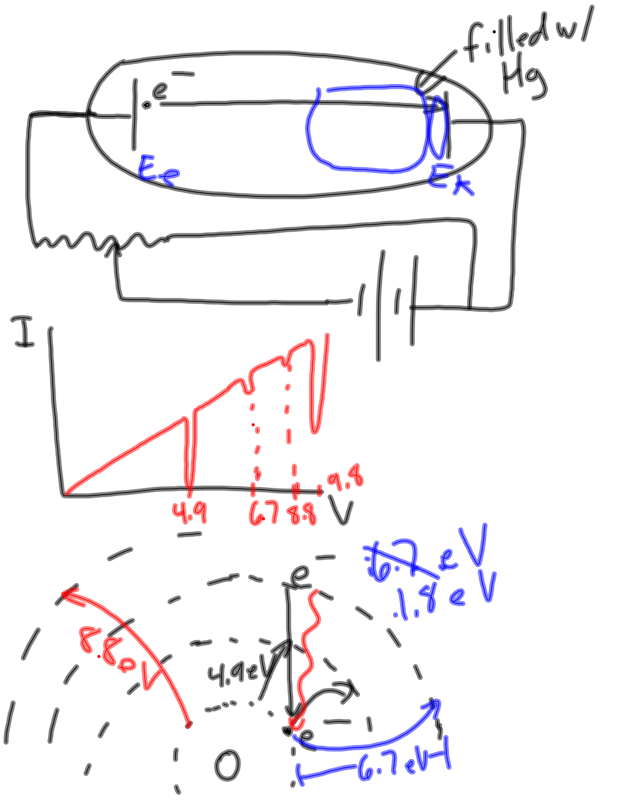
$q_2 = 79+$
$= 79(1.602\times10^{-19}\ C)$
$= 1.266\times10^{-17}\ C$

$r = \frac{2Kq_1q_2}{mv^2}$

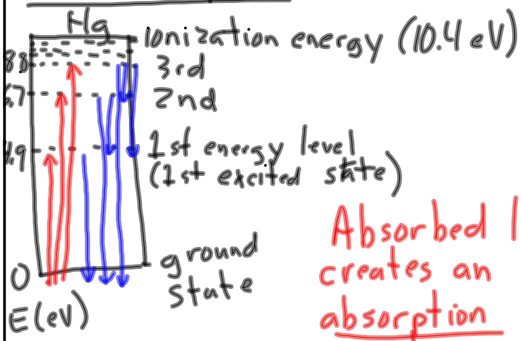
$= \frac{2(9\times10^9)(3.204\times10^{-19})(1.266\times10^{-17})}{(6.668\times10^{-27})(1\times10^6)^2}$

$= 1.09\times10^{-11}$ m

# The Franck-Hertz Experiment




## Atomic Spectra




Absorbed light creates an absorption spectrum

$E_p = 4.9\ eV$

$E_p = hf = \frac{hc}{\lambda} \therefore \lambda = \frac{hc}{E_p}$

$= \frac{(4.14 \times 10^{-15})(3 \times 10^{8})}{4.9}$

$= 2.53 \times 10^{-7}$

$= 253\ nm$

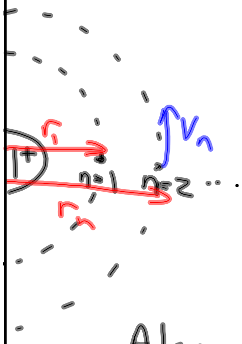
Emission Spectrum:

when $e^-$ jump back down to ground state (may be in steps)

$\lambda_{3-2} = \frac{hc}{E_p}$

$= \frac{(4.14 \times 10^{-15})(3 \times 10^{8})}{\dots}$

# Energy Levels of the Hydrogen Atom




$$E_n = E_K + E_e$$
$$= \frac{1}{2} m_e v_n^2 + \frac{K q_1 q_2}{r_n}$$

but $q_1 = e$, $q_2 = -e$

$$\therefore E_n = \frac{1}{2} m_e v_n^2 - \frac{Ke^2}{r_n} \quad (0)$$

Also $F_c = F_e$

$$\frac{m_e v_n^2}{\cancel{r_n}} = \frac{Ke^2}{r_n^{\cancel{2}}}$$

$$\therefore v_n^2 = \frac{Ke^2}{m_e r_n} \quad (1)$$

Sub (1) into (0)

$$E_n = \frac{1}{2} \cancel{m_e} \left( \frac{Ke^2}{\cancel{m_e} r_n} \right) - \frac{Ke^2}{r_n}$$

$$\boxed{E_n = -\frac{Ke^2}{2 r_n}} \quad (2)$$

According to quantum theory only specific E levels are possible $\therefore$ only specific r are possible

Bohr's theory: Possible E level are related to the deBroglie of the $e^-$

$\therefore$ the circumference of the orbit is $n\lambda_e$

$$\therefore 2\pi r_n = n\lambda_e$$

Recall $p = \frac{h}{\lambda}$ $\therefore \lambda_e = \frac{h}{m_e v_n}$

$$2\pi r_n = \frac{nh}{m_e v_n}$$

$$r_n = \frac{nh}{2\pi m_e v_n}$$ squa

$$r_n^2 = \frac{n^2 h^2}{4\pi^2 m_e^2 v_n^2}$$ sub

$$= \frac{n^2 h^2}{4\pi^2 m_e^{\cancel{2}} \left( \frac{Ke^2}{\cancel{m_e} r_n} \right)}$$

$$r_n^{\cancel{2}} = \frac{n^2 h^2 \cancel{r_n}}{4\pi^2 m_e K e^2} \quad (3)$$

Sub into (2)

$$E_n = \frac{-Ke^2}{2 r_n} = \frac{-Ke^2}{\cancel{2} \left( \frac{n^2 h^2}{\cancel{4}^{2}\pi^2 m_e \ldots} \right)}$$

$$= \frac{-Ke^2 (2\pi^2 \ldots}{n^2 h^2}$$

$$= \frac{-2\pi^2 m_e K \ldots}{n^2 h^2}$$

$m_e = 9.11 \times 10^{-31}$ kg

$k = 9 \times 10^9 \ \frac{Nm^2}{C^2}$

$e = 1.602 \times 10^{-19}$ C

$h = 6.63 \times 10^{-34}$

Heisenberg's Uncertainty Principle

↳ There is a certain amount of uncertainty in every measured value

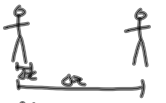
$\Delta x \rightarrow$ uncertainty in position

$x = 1.5\ m$ < $1.55\ m$, $1.45\ m$

$\therefore \Delta x = 0.1\ m$

Heisenberg's Uncertainty Principle

$\Delta x \Delta p \geq \frac{h}{2\pi}$ $(\hbar = \frac{h}{2\pi})$




Also $\Delta E \Delta t \geq \hbar$

Eg. What is the uncertainty in the position of an electron if its speed is measured to be $5.05 \times 10^6\ \frac{m}{s}$?

$m = 9.109\ 389 \times 10^{-31}\ kg$ 5.0 5.0

$\Delta v = 0.01 \times 10^6\ \frac{m}{s}$

$= 1 \times 10^4\ \frac{m}{s}$

$\Delta x \Delta p \geq \frac{h}{2\pi}$

$\Delta x \Delta(mv) \geq \frac{h}{2\pi}$

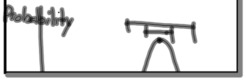
$\Delta x (m) \Delta v \geq \frac{h}{2\pi}$

$\Delta x (9.109\ 389 \times 10^{-31})(1 \times 10^4) \geq$

$\Delta x (9.109\ 389 \times 10^{-27}) \geq 1.0$

$\Delta x \geq 1.16 \times 10^{-8}\ m$

$\Delta x \geq 1 \times 10^{-8}\ m$




$\Delta m = 1 \times 10^{-6}$

$\Delta V = 1 \times 10^4$ $\Delta p$

$m = 2.2 \times 10^{-5}\ kg$ → $2.15 \times 10^{-5}$, → $2.25 \times 10^{-5}$

$V = 3.0 \times 10^5\ \frac{m}{s}$ → $3.05 \times 10^5$, → $2.95 \times 10^5$

$p = mv$ → $6.3425\ kg\frac{m}{s}$, → $6.8625\ kg\frac{m}{s}$ $\Big\}$ $\Delta p = 0.52\ kg\frac{m}{s}$

$= 0.5\ kg\frac{m}{s}$

THE END