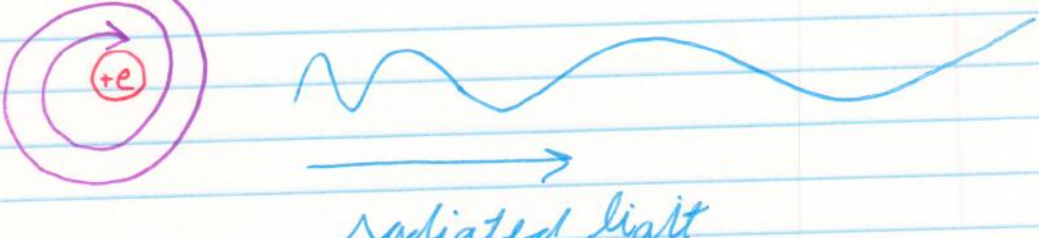
Bohr Atom & Line Spectra

Classical Radiation Theory

- Thomson & Rutherford know that e^{-1} must "revolve" around nucleus to avoid falling into it.

* • Maxwell E+M: e^{-1} revolves with frequency f, then emits radiation with frequency f.

→ But! As energy is radiated, e^{-1} should fall into a tighter orbit.



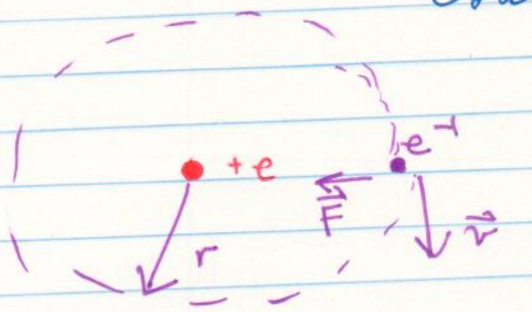
April 1913: Bohr "solves" the mystery and publishes "On the constitution of atoms & molecules"

Bohr proposes: (i) Classical radiation thy does not apply to e^{-1}

builds on Planck! { (ii) Only certain orbits are stable, separated by $hf = \Delta E$

HYDROGEN

Start + Finish
Course with Hydrogen atom!



Bohr model:

- circular orbit
- only certain orbits are stable
- jumping from one orbit to another absorbs or emits hf.

* not related to orbital ~~freq.~~ frequency!

- Angular momentum is quantized

$$m_e v r = n\hbar$$

$\hbar = h/2\pi$ Planck's constant $6.63\times10^{-34}\ \mathrm{J\cdot s}$

* Justify this using the idea of de Broglie that all matter is a wave with

$$\lambda = \frac{h}{p}$$

p momentum

$$f = \frac{E}{h}$$

** Stable states are thus ③
standing waves which
satisfy periodic boundy conditions.

Thus $2\pi r = n\lambda = n\left(\frac{h}{m_e v}\right)$

$\longrightarrow m_e v r = n\hbar$

Coulomb Potential $U = q\overset{\text{voltge}}{V} = \overset{\text{SI units}}{\frac{-ke^2}{r}} = \underbrace{\frac{-e^2}{4\pi\epsilon_0 r}}_{\text{cgs units}}$

$\overset{E}{\text{Total Energy}} = \overset{KE}{\text{Kinetic}} + U$

$= \frac{1}{2}m_e v^2 - \frac{ke^2}{r}$

Electrical force supplies centripetal force

$\frac{m_e v^2}{r} = \frac{ke^2}{r^2}$ [Note: Thus $v = \sqrt{\frac{ke^2}{m_e r}}$]

$KE = \frac{1}{2}m_e v^2 = \frac{ke^2}{2r}$

$\Longrightarrow E = -\frac{ke^2}{2r}$

Thus, for the orbits,

$m_e v r_n = n\hbar$

$$r_n = \frac{n\hbar}{m_e v} = \frac{n\hbar}{m_e}\sqrt{\frac{m_e r_n}{ke^2}}$$

$$r_n^2 = \frac{n^2\hbar^2}{m_e^2}\cdot\frac{m_e r_n}{ke^2}$$

$$\Longrightarrow \boxed{r_n = \frac{n^2\hbar^2}{m_e k e^2}} \qquad n = 1, 2, 3 \ldots$$

for $n = 1$, lowest orbit

$$r_{n=1} = a_0 = \frac{\hbar^2}{m_e k e^2} = 0.529\,\text{Å}$$ Bohr radius! Amazing!

Also: To ionize the atom, the radius of the lowest orbit sets the energy scale.

$$E_n = -\frac{ke^2}{r_n}$$

$$= -\frac{ke^2}{2a_0}\left(\frac{1}{n^2}\right) = \frac{-13.6\,\text{eV}}{n^2}$$

also explains correct emission spectra!

Correct ionization energy!!

What is missing in Bohr's model: 5

- Failed to predict intensity of spectral lines
- limited success for multi-electron atoms
- failed to produce time dynamics
- ignores wave nature / phenomenon
- no general quantization ~~scheme~~ scheme

$\Downarrow$

Need Quantum Mechanics
as developed by Heisenberg
Schrödinger
Dirac
⋮