V. de Broglie's Model of the Electron

A. Standing Wave

- a wave with fixed ends a distance L apart

COMPUTER ANIMATION

- allowed oscillation patterns (or "modes") have an integral number of half-wavelengths

that is, $L = n\left(\frac{\lambda}{2}\right)$ (n ↑ integer)

- the number of nodes in a standing wave $= n - 1$

$\lambda = \frac{2L}{n}$ so if L is constant,

↑ (# of nodes) ⇒ ↑ n ⇒ ↓ λ

An electron in an atom is a circular standing wave!

$\lambda = \frac{2L}{n}$ $L = 2\pi r$ (r: distance of e^- from nucleus)

n: quantum number (same as Bohr)

B. Interpreting / Improving the Bohr Model

- n is an integer because non-integral values of n would lead to unstable oscillation patterns (non-standing waves)
- changing n (by absorbing or emitting a photon) means you are changing the number of nodes in the e^- wave
- Effect of # of nodes on e^- <u>kinetic</u> <u>energy</u> (KE):

$$\lambda = \frac{2L}{n}$$ true for any standing wave

brand-new weird equation

$$\boxed{\lambda = \frac{h}{mv}}$$ "de Broglie wavelength"

h: Planck's constant

m: e^- mass

v: e^- speed

$$KE = \frac{1}{2} mv^2$$ definition of kinetic energy

↑ (# of nodes) ...

↓ L ...

i.e. the space the e^- occupies

(gloss over)

If potential energy (i.e. the attraction of the negatively-charged electron to the positively-charged nucleus) is all the e^- had to worry about, e^-'s would collapse into the nucleus instantaneously!

But now we have to worry about e^- KE as well:

$\lambda = \frac{2L}{n}$ Assume $n = 1$

If e^- collapsed into nucleus,

$L = 2\pi r = 2\pi$ (radius of nucleus)

$L \cong 2\pi(1 \times 10^{-15}\,m) = 6 \times 10^{-15}\,m$

so $\lambda = 2(6 \times 10^{-15}\,m) \cong 1 \times 10^{-14}\,m$

and $\lambda = \frac{h}{mV} \Rightarrow V = \frac{h}{m\lambda}$

$$V = \left(\frac{6.6 \times 10^{-34}\,\cancel{J}\cdot s}{\cancel{particle}}\right)\left(\frac{\cancel{particle}}{9.1 \times 10^{-31}\,\cancel{kg}}\right)\left(\frac{1}{1 \times 10^{-14}\,\cancel{m}}\right)\left(\frac{\cancel{kg}\,m^{\cancel{2}}\,s^{-\cancel{2}}}{1\,\cancel{J}}\right)$$

$V = 7 \times 10^{10}\,m\,s^{-1}$ vs. speed of light ($3 \times 10^8\,m\,s^{-1}$)

↑ impossible to move this fast!

∴ because an e^- is a standing wave, it cannot be confined to the nucleus

- So, where is the electron?

  Wherever the electron wave is oscillating ... simultaneously!

  - the only thing we know for sure is where the e^- cannot be found (i.e. at a node)
  - the fact that an e^- is a wave means that it is delocalized ... it cannot be pinned down to any one spot

C. What's Wrong with de Broglie?

⊖ Still can't predict the properties of atoms/ions with more than 1 e^-...

∴ need a three-dimensional version of de Broglie's theory, that is, quantum mechanics