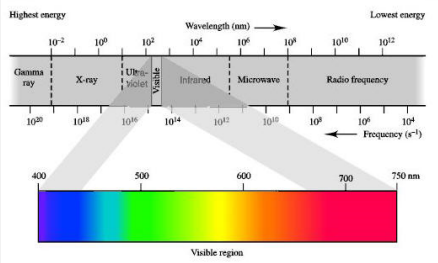
[TP] The wavelength of the electron wave in the ground state of H atom is about the size of the atom. In what region of the spectrum is light of similar wavelength?

0% 1. Radio
0% 2. Microwave
0% 3. Infrared
0% 4. Visible
0% 5. Ultraviolet
0% 6. X-ray
0% 7. Gamma ray



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Lecture 28 CH101 A1 (MWF 9:05 am)

Monday, November 12, 2018

For today ...

- Electron waves and quantization (de Broglie)
- Hydrogen atom electron clouds

Next lecture: Energy of hydrogen atom electron clouds ; Revisit: How light and matter exchange energy ; H atom energy diagrams: Balmer's formula ; H atom energy diagrams: Beyond Balmer's formula

Prepare: Hydrogen atom family album, https://goo.gl/XPkcxv

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Electron waves and quantization (de Broglie)

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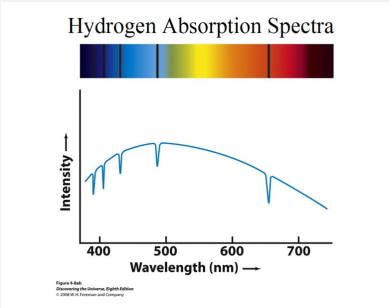
Electron waves and quantization (de Broglie)

Only certain colors = quantization



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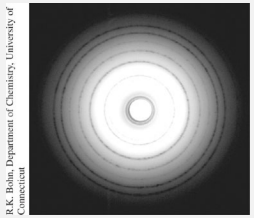
Electron clouds are built from waves

By analogy to the energy-frequency relation for light,

$E_{\text{photon}} = h\nu_{\text{light}}$

De Broglie guessed that electron clouds are built from waves.

This guess was confirm by diffraction of electrons by the lattice of ions in a salt crystal.



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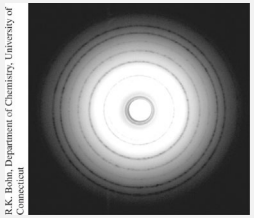
Electron clouds are built from waves

The electron wave wavelength

$\lambda_{\text{electron}} = h/p_{\text{electron}}$

is inversely proportional to electron momentum

$p_{\text{electron}} = mu$



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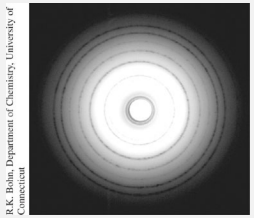
Electron clouds are built from waves

Show that the units of

$\lambda_{\text{electron}} = \frac{h}{p} = \frac{h}{mu}$

are correct.

$\lambda_{\text{electron}} \propto \frac{\text{J s}}{\text{kg}\frac{\text{m}}{\text{s}}} = \frac{\text{kg}\frac{\text{m}^2}{\text{s}^2}\text{s}}{\text{kg}\frac{\text{m}}{\text{s}}} = \text{m}$



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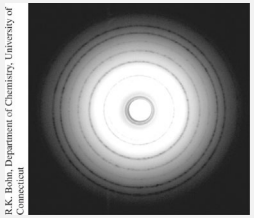
Electron clouds are built from waves

One crucial thing to understand:

Electron waves are not anything physical waving in space.

Rather, they are abstract mathematical waves.



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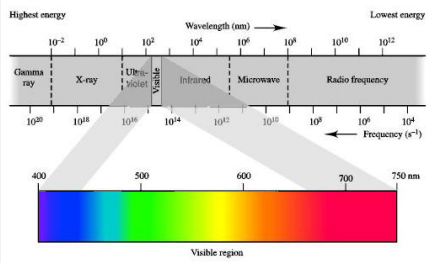


Electron "waves"

We can illustrate electron waves and their properties with wave on a spring.

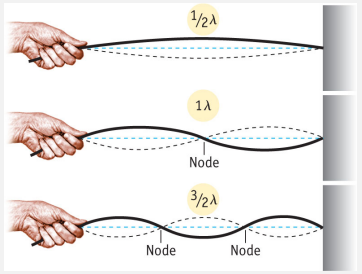
Electron "waves"

Big idea 1:

Integer number of *loops*, $\lambda/2$, must "fit" in the atom

Integer number of loops fit in the atom

- 1 loop
- 2 loops
- 3 loops



Electron "waves"

Big idea 2:

More loops, …

more energy

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Electron "waves"

We have illustrated electron waves and their properties with a spring.

What corresponds to the spring?

Space is permeated by what is called the quantum field.

The spring represents the quantum field.

Excitations of the quantum field (one loop, two loops, etc.) are electron waves.

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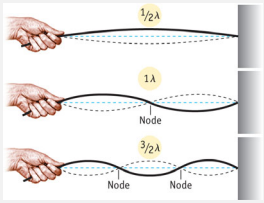
Hydrogen atom electron clouds

1D electron cloud:

- 1D example of a standing wave
- Major Lesson: lowest energy has 1 loop (0 nodes)
- Major Lesson: more loops, more energy



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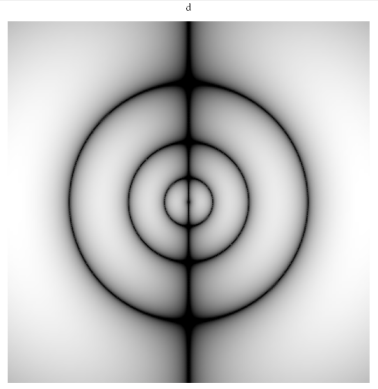
Extend to 3D electron cloud: http://goo.gl/XPkcxv



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Hydrogen atom family album: http://goo.gl/XPkcxv

1D electron cloud:

- 1D example of a standing wave
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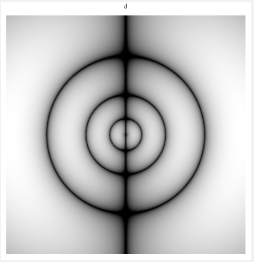

Extend to 3D electron cloud:

- Atoms are spheres!! (not wires)
- Two types of loops:
  - radial
  - angular (nodal planes)

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Clouds and probability

The density of an electron cloud is a measure of the fraction of the electron in that region.

For this reason, clouds are sometimes referred to in terms of probability density.

It is crucial to understand that the cloud *is* the electron, and not a time exposure of a point particle.

Probability density is due to spatial extent rather than motion.

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Radial loops

Concentric rings around nucleus
(distance from the nucleus)

j = # radial loops

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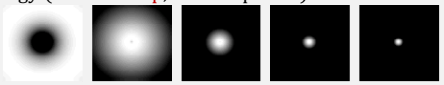
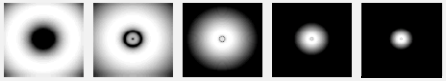
Radial loops only (known as "s")

Lowest Energy (1 radial loop, 0 nodal planes):



2nd Lowest Energy (2 radial loops, 0 nodal planes):



Etc.

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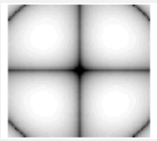
Nodal planes

- Will look like planes (lines) of zero probability



l = # of nodal planes

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Radial + 1 nodal plane (known as "p")

Lowest Energy (1 radial loop, 1 nodal plane):

2nd Lowest Energy (2 radial loops, 1 nodal plane):

Etc.

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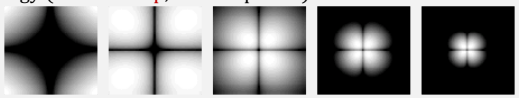
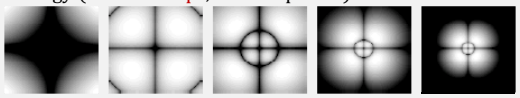
Radial + 2 nodal planes (known as "d")

Lowest Energy (1 radial loop, 2 nodal planes):



2nd Lowest Energy (2 radial loops, 2 nodal planes):



Etc.

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