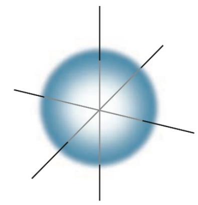
CH101 - Quantum Numbers Handout

Wavefunctions, Quantum Numbers, and the nature of electrons

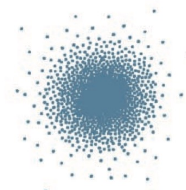
Electrons in atoms behave as waves (delocalized).

Attempts to "measure" e^-'s cause them to localize (particle).

The picture in the book is the result of ***many*** electrons measured! 1 electron (b) = 1 dot in (a)



(b)



(a)

The Wavefunction (ψ) of an electron is the MATHEMATICAL function describing the electron wave.

Just like $\sin(x)$ describes a 1D wave, ψ is a function of (n, l, m_l, m_s): that describes the 3D wave that **IS** the electron.

n, l, m_l, m_s are the quantum numbers that describe the wave!

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Quantum numbers (*n*, *l*)

n = total # of loops (or # nodes–1) (principal quantum number)

⟶ Energy of the wave: $E_n = -(2.18\text{ aJ})Z^2/n^2$

⟶ Size of the wave: radius = 52.9 pm n^2/Z

l = # of nodal planes (0, …, n–1) (azimuthal quantum number)

⟶ Wave of the shape (sphere, dumbbell, etc)

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Quantum numbers (m_l, m_s)

m_l magnetic quantum number 0, ±1, … ±*l*

(*m_l* is about the orientation)

(Check out **falstad.com/qmatom** to visualize them!)

m_l = 0:	p_z	d_{z2}	
m_l = ±1:	p_x, p_y	d_{xz}	d_{yz}
m_l = ±2:		d_{x2-y2}	d_{xy}

m_s spin quantum number -½, +½

Nothing is spinning!!

This is an intrinsic property of the electron (no reason) – magnets have two orientations, so too here.

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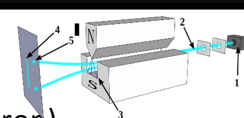
Electrons have a quantized magnetic moment



- Stern and Gerlach using silver atoms (which have a single valence electron)
- Silver atoms travelling through an uneven magnetic field are deflected up or down: (1) furnace, (2) beam of silver atoms, (3) inhomogeneous magnetic field, (4) classically expected result, (5) observed result.
- Electrons have a magnetic moment that can be aligned in only two opposite directions.
- The magnetic moment was thought to be due to the electron spinning on its axis. We now know this is not the case (it would have to spin unphysically fast).

Rather, it is now understood instead to be an **intrinsic property of the electron**.

Nonetheless, the magnetic moment is referred to as the "spin" of the electron.

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Common parlance and notation

Electron: **unique set of 4 QN's** (n, l, m_l, m_s) that describe a unique wave

- Two electrons cannot have the same set of QNs (Pauli exclusion principle)
- The electron **IS** the **WAVE** (e.g., $\psi_{1s}, m_s = +1/2$)

Orbital: the unique set of first three QNs for an electron in an atom (n, l, and m_l)

- There can be **exactly two** electrons with the same (n, l, and m_l)
- The electron isn't ***IN*** in the orbital; it ***IS*** the orbital (e.g., $\psi_{3d_{xy}}$)

Subshell: subset of the orbitals with the same energy and shape (n and l)

- e.g., 2p subshell is $2p_x + 2p_y + 2p_z$; 4d subshell is $4d_{xy}$, $4d_{zy}$, $4d_{xz}$, $4d_{x2-y2}$, $4d_{z2}$

Shell: set of (degenerate, in H) orbitals (same energy, same n)

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