NOTES #21/Quantum Theory#3/AP CHEMISTRY

I. The Dual Nature of the Electron

- So far, we've learned that electromagnetic radiation has both ___________________ and ___________________ characteristics.

  - How is electromagnetic radiation wave-like? ____

  - How is electromagnetic radiation particle-like? ____

- Louis de Broglie (French Physicist) in 1924 proposed that particles, too, have both wave-like and particle-like behavior. De Broglie related these two characteristics via the following expression:

"matter wave equation"

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

- **λ** = wavelength
- **h** = Planck's Constant (6.63×10^{-34} J·s)
- **mv** = Mass (kg) x Velocity (m/s).......why does m have to be in kg?

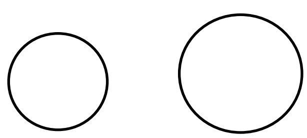
- If de Broglie's expression is true, then *any* particle with a mass and a velocity has an associated wavelength.

  - Why don't we ever hear about the waves emanating from flying baseballs???

  ** As the mass ___________________, the wavelength __________________.

To put this in perspective, the λ of a fast served tennis ball (0.06kg) moving at 62 m/s (~140 miles/hr) is ____________________m whereas the λ of an electron moving at a speed of 62 m/s is ______________________m (in the ______ range of the ER spectrum). The wavelength of a tennis ball, or any other macroscopic matter, is not easily ____ or significant.

-So, why do we CARE? The wave properties of an electron ARE significant! The wave properties of electrons explain WHY electrons with a certain energy (and corresponding λ) can only exist in certain energy levels with a certain discrete distance from the nucleus.



- Think of an electron as behaving like a circular _________________ wave. The length of the wave must fit the circumference of the "orbit" exactly....otherwise, the wave would eventually ____itself out.

II. Quantum Mechanics or Wave Mechanics

A. Since electrons are now characterized by both particles-like *and* wave-like, describing the motion of an electron is much more complicated and requires the use of complex "wave functions (Ψ^2)." The actual use of these wave functions is (from the perspective of this class) unnecessary. However, it is important to understand the results of using these wave functions, which are summarized below:

1. We can't *simultaneously* know the exact momentum (m·v) and ____________________ of an electron with certainty. This is referred to as the **Heisenberg Uncertainty Principle**. Stated mathematically:

$$\Delta x \Delta mv \geq \frac{h}{4\Pi}$$

Δx = uncertainly in measuring position

Δmv (also known as Δp) = uncertainty in measuring mass and velocity (momentum)

** In other words, ____

As Δx (position) becomes smaller (more known), Δp (momentum) becomes _______________________(less known).

2. Although we can't pinpoint the exact location (and momentum) of an electron in an atom, we *can*, using wave functions, define a probable region where an electron with a certain energy would most likely be found.

3. Now, instead of talking about Bohr's well-defined "orbits" we talk about ELECTRON CLOUDS, probability and about atomic oribitals...

4. To describe the distribution of electrons in atomic orbitals (or to solve wave functions), FOUR quantum numbers are required, n, *l*, m_l, m_s**** as discussed in the next section.

B. THE QUANTUM NUMBERS!!!

1. **The Principle Quantum Number (n)**
   - n may have integer values ranging from 1 to whatever....
   - Represents the principal ______________________________in which the e^- is located and is related to the average _______________________ of the electron from the nucleus.
   - The _______________ n, the _________________________ away from the nucleus, the ________________ unstable.
   - Tells the ______________________________ of subshells in an energy level.

   EX: n=3 means this energy level has ____.

2. **The Angular Momentum Quantum Number or Azimuthal Quantum Number(*l*)**
   - for a given value of n, *l* can have integral values from 0 to (n-1) EX: for n=2, *l* could be _______________
   - Represents the _________________ of the orbital or sub-level.
   - different *l* values represent different shaped orbitals:

l is equal to:	0	1	2	3	4	5.........
Type of orbital	s	p	d	f	g	h.........

3. **The Magnetic Quantum Number (m_l)**
   - m_l has integral values from -*l* to +*l* or $m_l = 2l + 1$
   - Represents the different __________________________ of orbitals in space.

     ex: *l* = 1 (a p orbital), m_l = _______________....in other words, there are 3 different p orbitals, each one of a different orientation in space.
   - A MAXIMUM OF $2e^-$ CAN FIT IN ANY ONE ORBITAL!!

l value	Type of sublevel	Possible m_l value	Total # of orient.	Max # of e^-	Illustration	Comments
0	s	0	1	2		- spherical shaped
1	p	-1, 0, +1		6		___________________
2						___________________
3						___________________

4. **The Magnetic Spin Quantum Number (m_s)**
   - m_s is either +1/2 or -1/2
   - Represents the ______________ of an electron, either counterclockwise or clockwise.
   - Explanation: electrons spin on their own little axis......
   - An electron can either spin clockwise (+1/2) or counterclockwise (-1/2)

****m_s is not needed to solve a wave function but is necessary to fully designate an e^- to an orbital.