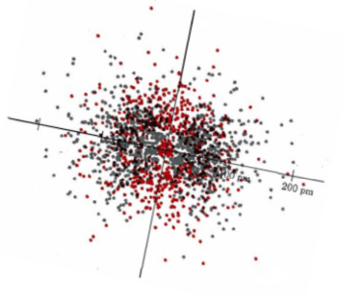
The Quantum Numbers



Before we begin learning about quantum numbers let's look at some of the reasons for even studying the electron or quantum numbers.

What were the three main questions concerning the electron?

1. ____

2. ____

3. ____

Why is it important to know these things about the electron?

____

____

The purpose of this handout is to finish answering the second question concerning electrons. Then, when we understand the theory behind the location of the electron, we open the door to the third question concerning electrons. This in turn helps us understand how the elements form compounds and how chemical reactions take place.

Quantum Numbers

Quantum numbers describe the orbital occupied by an electron in terms of:

1. **distance** from the nucleus (energy level)
2. **shape** (type of orbital)
3. **position** with respect to 3-D
4. **direction** of spin in the orbital

Principal Quantum Number

The first quantum number (**n)** is the principal quantum number and **describes the main energy level (shell) of the electron.** This energy level is the probable distance the electron is from the nucleus.

The maximum number of electrons in any one energy level is $\mathbf{2n^2}$. So as **n** increases, the energy and number of electrons in a level will increase.

Example $n=1 \rightarrow 2(1)^2 = 2$ electrons $\therefore$ energy level one can have only 2 electrons maximum

$n=2 \rightarrow 2(2)^2 = 8$ electrons $\therefore$ energy level two can have only 8 electrons maximum

$n=3 \rightarrow 2(3)^2 = 18$ electrons $\therefore$ energy level three can have only 18 electrons
maximum

$n=4 \rightarrow 2(4)^2 = 32$ electrons $\therefore$ energy level four can have only 32 electrons maximum

$n=5 \rightarrow 2(5)^2 = 50$ electrons $\therefore$ energy level five can have only 50 electrons maximum

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The Angular Momentum Quantum Number

The second quantum number (ℓ) is the angular momentum quantum number and **describes the shape or type of orbital**. Within an energy level there are four known possible sub energy levels each with a characteristic shape.

The value of the sub energy levels can be 0 to (n-1). However, it is a common practice to use the letters **s**, **p**, **d**, and **f** to represent these subshells instead of the numbers. An atom at ground state never has electrons higher than the f subshell, but **excited electrons** may go to higher levels and even out of the atom ($n = \infty$).

The number of **sub energy levels** or possible **orbital shapes** in any main energy level is equal to the value of **n**. If n = 1 then there is only one subshell, **s**. If n = 2 then there are two possible subshells, **s** and **p**, etc.

Example	**If..**	n = 1	**and..**	ℓ = 0	**then..**	1s
		n = 2		ℓ = 0, 1		2s 2p
		n = 3		ℓ = 0, 1, 2		3s 3p 3d
		n = 4		ℓ = 0, 1, 2, 3		4s 4p 4d 4f
		n = 5		ℓ = 0, 1, 2, 3, 4		5s 5p 5d 5f 5g

Magnetic Quantum Number

The third quantum number (m_ℓ) is the magnetic quantum number and **describes the electrons position in space with respect to the x, y, and z-axes.**

The **s** subshell has only **one** possible position in space, the **p** subshell has **three** possible positions, the **d** subshell has **five** possible positions, and the **f** subshell has **seven** possible positions. Each possible position is an orbital and each orbital can have two electrons.

s-sublevel has one position	m_ℓ = 0	1 orbital
p-sublevel has three positions	m_ℓ = -1, 0, 1	3 orbitals
d-sublevel has five positions	m_ℓ = -2, -1, 0, 1, 2	5 orbitals
f-sublevel has seven positions	m_ℓ = -3, -2, -1, 0, 1, 2, 3	7 orbitals

Spin Quantum Number

The fourth quantum number (m_s) is the spin quantum number and **describes the electron spin.**

If two negatively charged particles occupy the same orbital, how do they keep from repelling one another?

It is possible the electrons spin in opposite directions and therefore, produce opposite magnetic fields that attract rather than repel one another. Scientist refer to these possible spins as (+1/2) and (-1/2).

Wolfgang Pauli

The fact that each electron in an orbital must have different spin quantum numbers led Wolfgang Pauli to the conclusion that no two electrons in the same atom can have the same four quantum numbers. This conclusion still holds true and is known as the **Pauli Exclusion Principle**.

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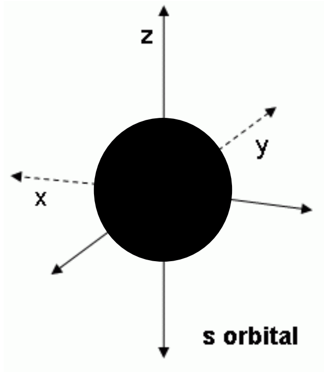
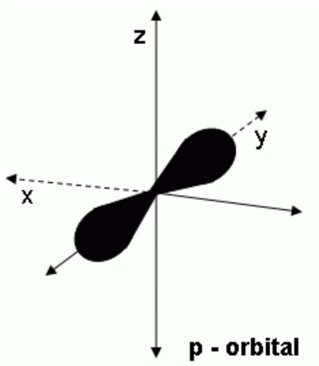
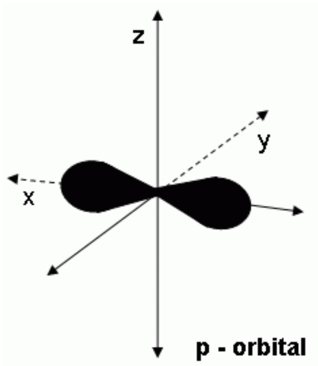
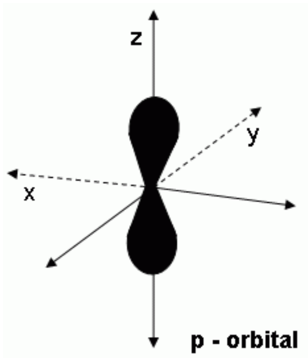
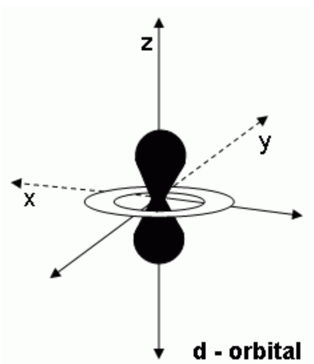
Orbital Shapes

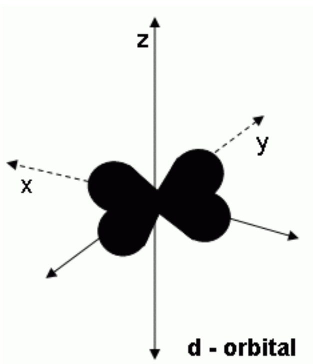


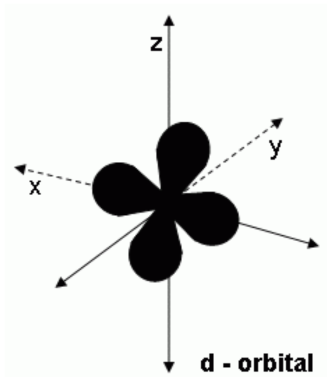


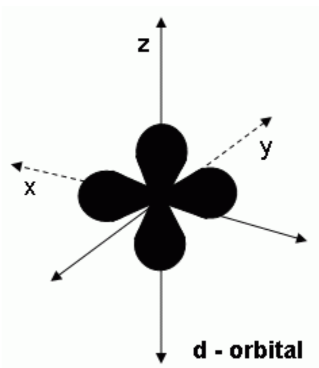


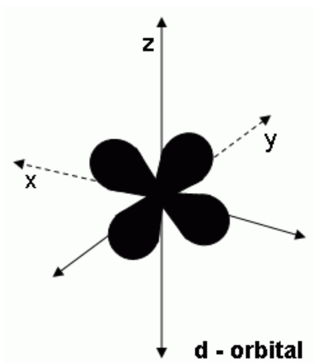












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Think It Through

- What are three main questions about the electron?
- Why bother with the electron?
- What are quantum numbers?
- What do quantum numbers describe?
- What are orbitals?
- What are the orbital shapes?
- What is Pauli Exclusion Principle?

Answer the Following:

1) What are the possible values of ℓ, if n = 2 ? ______ and ______

2) When ℓ = 1, the values of m_ℓ can be ______ and the subshell has the letter label _________.

3) When ℓ = 2, this is called a _________subshell.

4) When a subshell is labeled s, the value of ℓ is _______ and m_ℓ has the value __________.

5) When a subshell is labeled p, there are _____orbitals within this shell.

6) When a subshell is labeled f, there are _________values of m_ℓ and there are _____orbitals within the subshell.

Vocabulary

shell	energy levels	sub energy levels
orbital	quantum numbers	

Ideas

principal quantum number	electron arrangement
angular momentum quantum number	electron configuration
orbital quantum number	orbital shapes
spin quantum number	Pauli Exclusion principle

Videos

Quantum Numbers
Electron Configuration
Writing Quantum Numbers

“What we observe as material bodies and forces are nothing but shapes and variations in the structure of space." – Erwin Schrodinger

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