

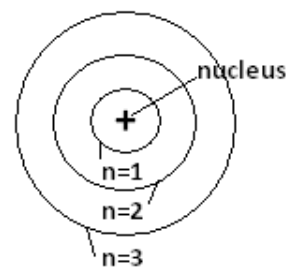
Quantum Numbers

Chem12A, Organic Chemistry I

Quantum numbers work like *addresses* for electrons in an atom. To narrow down your intended recipient, you would write the state → city → street → street number to tell the post office where to go. Quantum numbers work the same way: energy level → type of orbital → orientation of orbital → orientation of electron. **Every electron in an atom will have a unique set of quantum numbers in the form $[n, l, m_l, m_s]$.**

Principal Quantum Number ($n = 1, 2, 3, 4, \dots \infty$)

The principal quantum number, n , defines the *energy level or shell* of the electron. It is the first quantum number that must be determined, as it defines the available values for all other quantum numbers. Think of Bohr's model for the atom; n defines the ring on which the electron resides.



The value of n tells you how many levels away from the nucleus the electron is. The *valence shell* of an atom is the **highest occupied shell** and is mathematically equivalent to the period of the element (i.e., H is in period 1, so the valence shell for H is $n = 1$).

Azimuthal (Angular Momentum) Quantum Number ($l = 0, 1, 2, \dots (n-1)$)


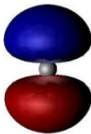
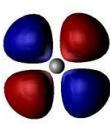

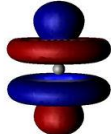
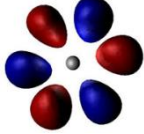
The azimuthal, or angular momentum, quantum number, l , defines the *type or shape* of the orbital where the electron most probably resides. It is the second quantum number to be determined as its value relies only on n (i.e., if $n = 2$, then $l = 0$ or 1 since $n - 1 = 1$). Each type of orbital has a unique number of *nodes* (e.g., where the wave changes phases) which is mathematically equivalent to l .

If $l = 0$, the electron is in an **s-orbital** that has 0 nodes.

If $l = 1$, the electron is in a **p-orbital** that has 1 node.

If $l = 2$, the electron is in a **d-orbital** that has 2 nodes.

If $l = 3$, the electron is in an **f-orbital** that has 3 nodes.

s-orbital	p-orbital	d-orbital	f-orbital
		 	 

Magnetic Quantum Number ($m_l = -l \dots 0 \dots +l$)

The magnetic quantum number, m_l , defines the *orientation* of the orbital in which the electron inhabits. The number of m_l values is called the *degeneracy*, or the **number of orbitals in the atom that are at the same energy level**. Note that to have the same energy, the orbitals must be on the same energy level as well as be the same type of orbital (n and l values are equal). A 2s orbital is not degenerate (e.g., the same energy) with a 2p or a 1s orbital.

The m_l values are entirely dependent on the l values; each type of orbital has a set degeneracy.

For an *s-orbital*, $m_l = 0$, and degeneracy = 1.

For a *p-orbital*, $m_l = -1, 0, +1$, and degeneracy = 3.

For a *d-orbital*, $m_l = -2, -1, 0, +1, +2$, and degeneracy = 5.

For an *f-orbital*, $m_l = -3, -2, -1, 0, +1, +2, +3$, and degeneracy = 7.

NOTE: A set of 2p orbitals and 3p orbitals may have the same degeneracy value, but they are **NOT** degenerate with each other. They both include three total orbitals, but they are not at the same energy: they have different n values.

Spin Quantum Number ($m_s = -\frac{1}{2}, +\frac{1}{2}$)

The spin quantum number, m_s , is completely independent of the values of n , l , and m_l . It is **always** $+\frac{1}{2}$ for an electron who has its spin oriented *up*, and $-\frac{1}{2}$ for an electron who has its spin oriented *down*. This means that there are only **two electrons allowed per orbital, no matter the energy level, shape, or orientation** (i.e., a 1s orbital holds 2 electrons, as does 4d orbital).

As of yet, we cannot determine whether an electron is pointed up or down, so it can be assumed **always** that $m_s = \pm \frac{1}{2}$

TO SUMMARIZE:

If n is:	then l can be:	so m_l is:	with a degeneracy of:	and m_s as:
1	0	0	1	$-\frac{1}{2}, +\frac{1}{2}$
2	0	0	1	$-\frac{1}{2}, +\frac{1}{2}$
	1	-1, 0, 1	3	$-\frac{1}{2}, +\frac{1}{2}$
3	0	0	1	$-\frac{1}{2}, +\frac{1}{2}$
	1	-1, 0, 1	3	$-\frac{1}{2}, +\frac{1}{2}$
	2	-2, -1, 0, 1, 2	5	$-\frac{1}{2}, +\frac{1}{2}$
4	0	0	1	$-\frac{1}{2}, +\frac{1}{2}$
	1	-1, 0, 1	3	$-\frac{1}{2}, +\frac{1}{2}$
	2	-2, -1, 0, 1, 2	5	$-\frac{1}{2}, +\frac{1}{2}$
	3	-3, -2, -1, 0, 1, 2, 3	7	$-\frac{1}{2}, +\frac{1}{2}$