5.9: Quantum Numbers (Electronic)

A characteristic of the diagram Figure 1 in Electron Waves in the Hydrogen Atom is that it has been assigned an identifying label, namely, 1*s*. This enables us to distinguish it from other wave patterns the electron could possibly adopt if it moved about the nucleus with a higher energy. Each of these three-dimensional wave patterns is different in shape, size, or orientation from all the others and is called an **orbital**. The word *orbital* is used in order to make a distinction between these wave patterns and the circular or elliptical *orbits* of the Bohr picture shown in The Wave Nature of the Electron.

Principal Quantum Number "n"

In the case of a particle in a one-dimensional box, the energy was determined by a positive whole number *n*. Much the same situation prevails in the case of the hydrogen atom. An integer called the **principal quantum number**, also designated by the symbol *n*, is used to label each orbital. The larger the value of *n*, the greater the energy of the electron and the larger the average distance of the electron cloud from the nucleus. The energy increases with n, in part, because the total number of nodes is n-1 for each wavefunction in shell n.

Angular Quantum Number "l"

The next quantum number, represented by *l* and called the "angular quantum number," can be any value in the range 0, 1, 2, ... *n* - 1. As we have seen in the case of 2-dimensional drum vibrations, *l* specifies the number of planar nodes in the wavefunction. This number represents the angular momentum of the orbital, and is important because it determines the shape of the orbital. This number is responsible for the s, p, d, f, etc., character of the orbital. $l = 0$ corresponds to an s orbital, $l = 1$ denotes a p orbital, and so forth.

Magnetic Quantum Number "m_l"

The "magnetic quantum number" corresponds to the projection of the orbital along an axis, i.e. when in three-dimensional space, along the x, y, or z axis. This value falls in the range of $-l, -l + 1, \ldots -1, 0, 1, \ldots l - 1, l$.

Spin Quantum Number "m_s"

The fourth quantum number, known as the "spin quantum number," refers to the intrinsic "spin" of the electron. This quantum number may hold only two values, either -1/2 or +1/2. *The Pauli Exclusion Principle* states that each electron must have a *unique* set of four quantum numbers, so if two electrons are paired together in an orbital, they share three quantum numbers and must have opposite spin quantum numbers. This electron spin property is what causes a substance to be *paramagnetic* or *diamagnetic*, because a moving charge always creates a magnetic field.

Magnetic Properties

Substances whose atoms, molecules, or ions contain unpaired electrons (which must be in different orbitals) are weakly attracted into a magnetic field, a property known as **paramagnetism**. This is because the Spin Quantum Number for the substance will not be zero since each electron will not have a partner to cancel. Paramagnetism is typically 0.1% as strong as the familiar "ferromagnetism" of common magnets.

Video 5.9.1Example of paramagnetism. *Liquid oxygen is held in a magnetic field but liquid nitrogen is not since the former is paramagnetic (Demo of Liquid Oxygen's paramagnetism [www.youtube.com]).*

Most substances have all their electrons paired. This means that each electron's spin number will be canceled by another electron (although they're usually in the same orbital, they need not be). The net spin will be zero for the substance, and it will not be attracted into a magnetic field, but actually repelled slightly. The repulsion is typically 0.1% as great as paramagnetic attraction. This property is known as **diamagnetism**.

Hence measurement of magnetic properties can tell us whether all electrons are paired or not.

Video 5.9.2 *Example of diamagnetism. This is video footage of an experiment at the High Field Magnet Laboratory in The Netherlands. Suppressed Anti-Gravity Technology - Diamagnetic Levitation [www.youtube.com]*

There are several other videos on YouTube showing

- diamagnetism of grapes (mostly water)
- diamagnetism of water

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