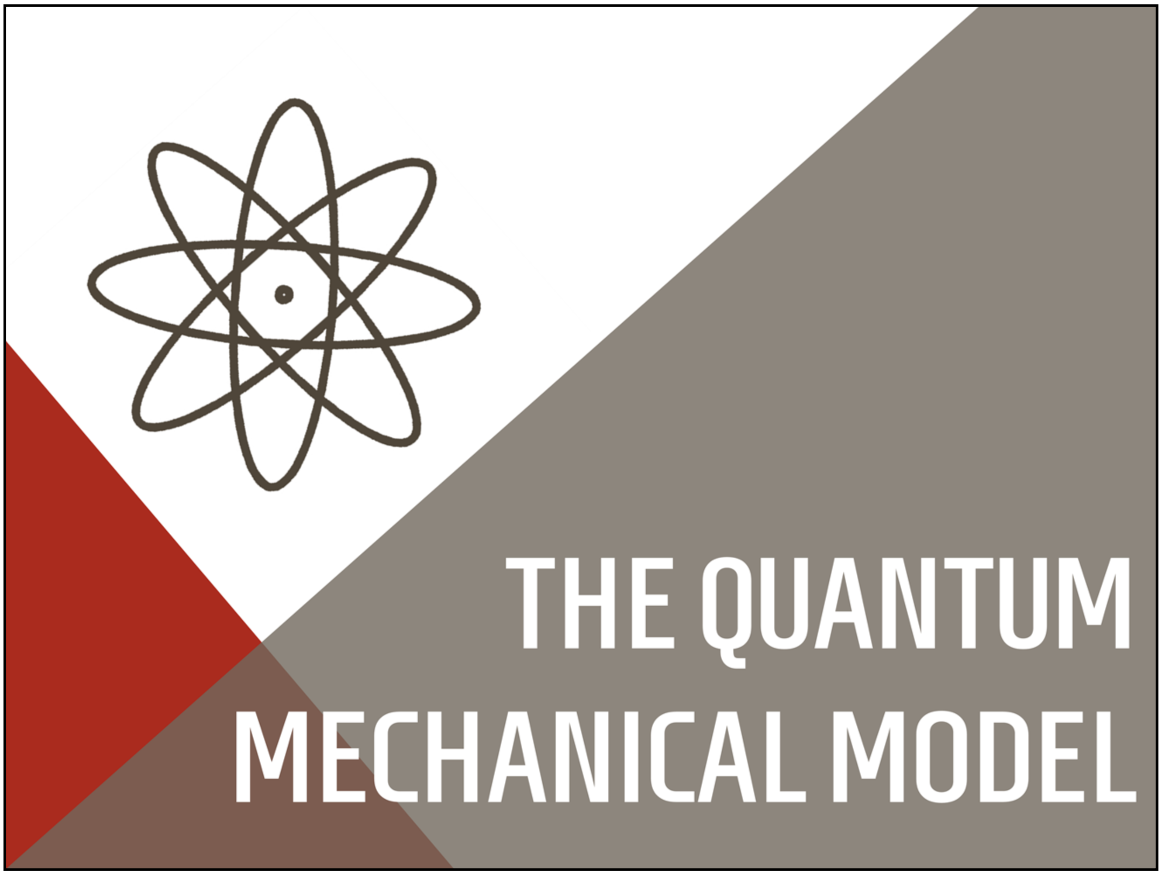
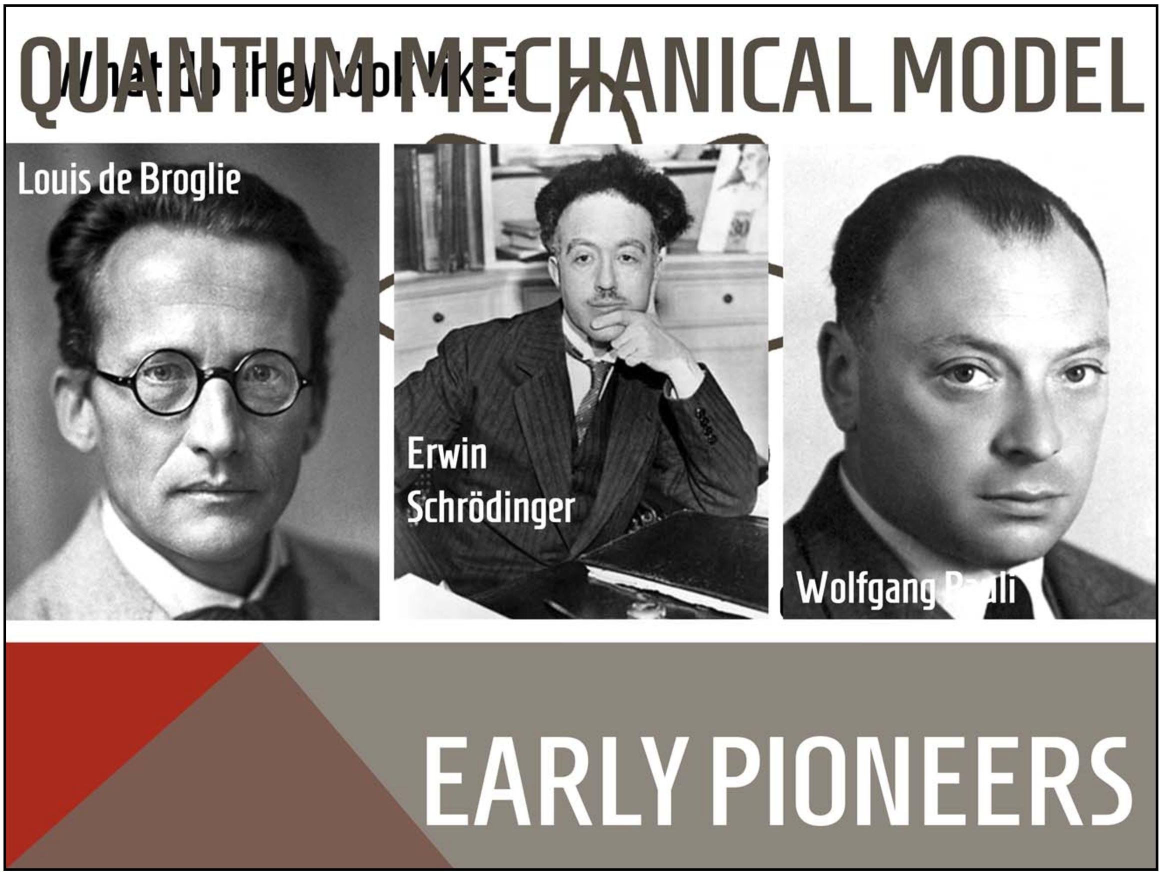
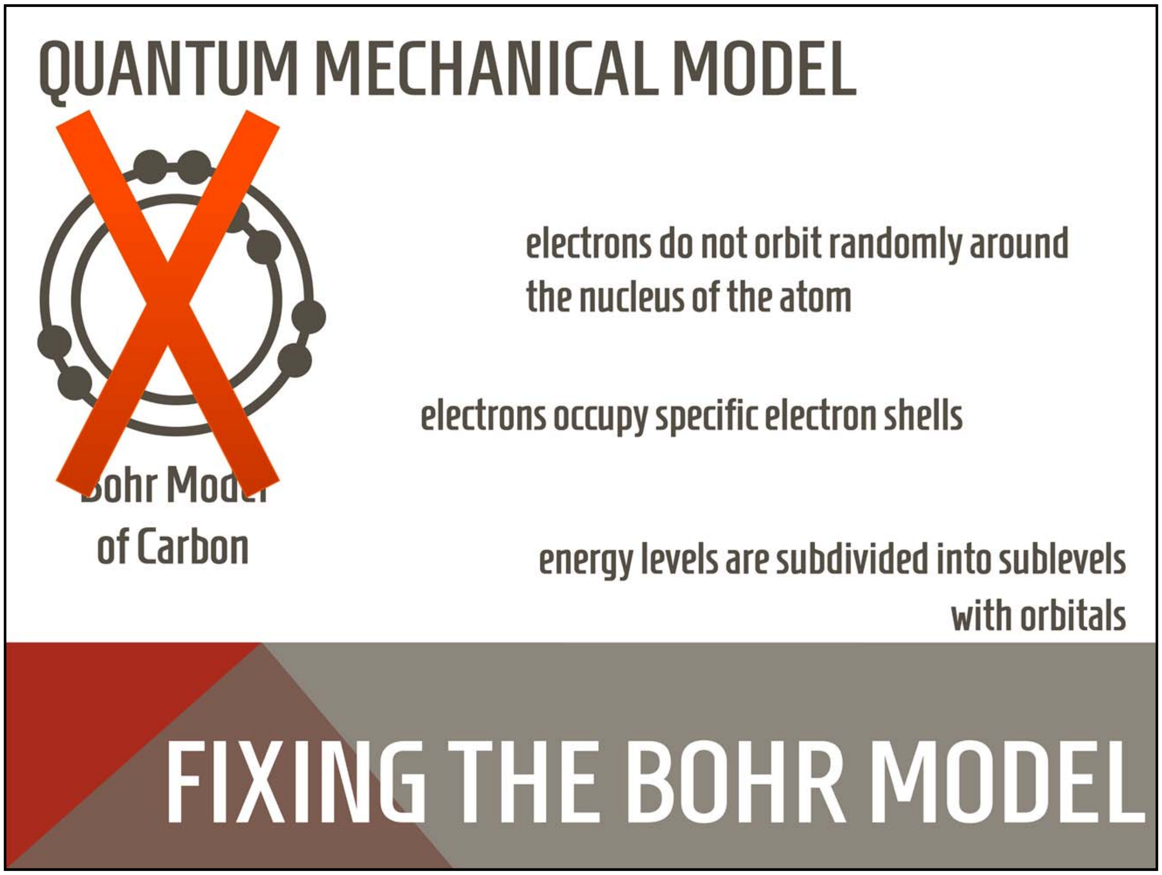


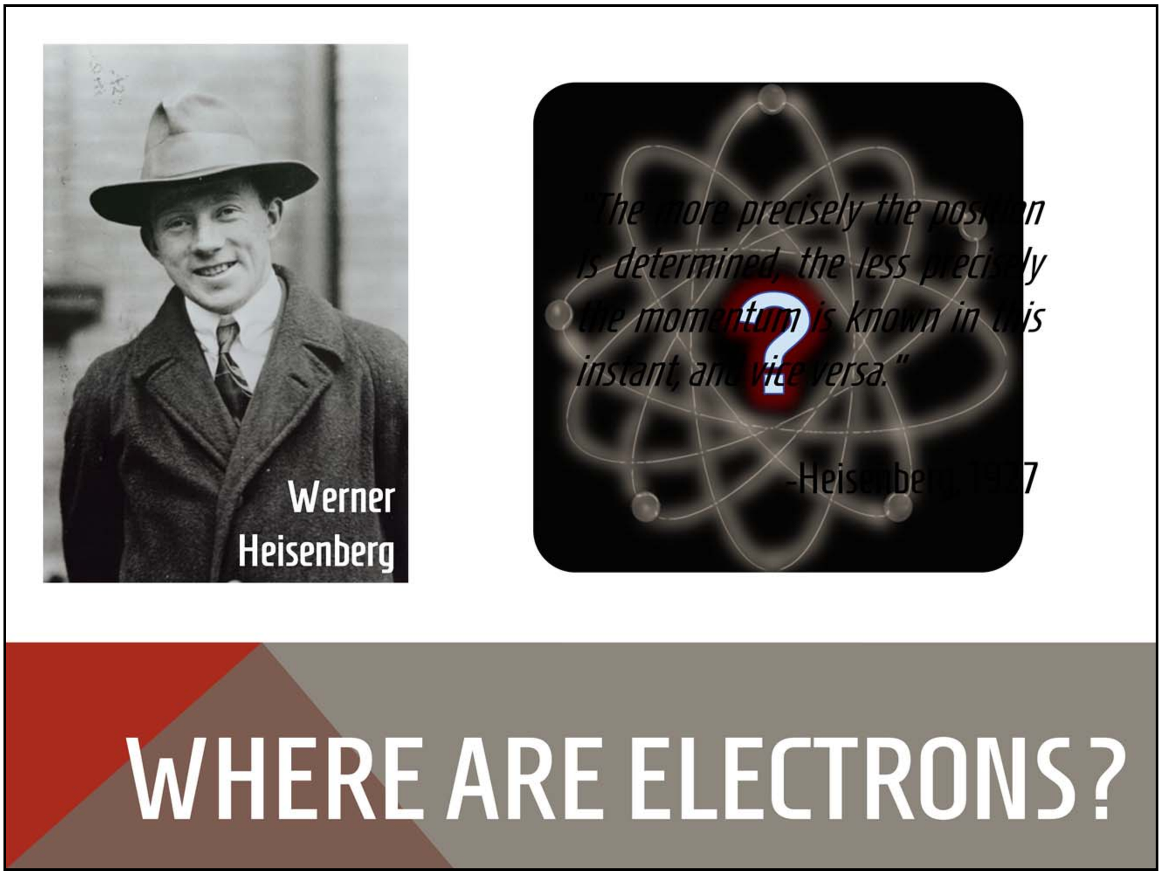
The Quantum Mechanical Model



What do atoms really look like? Where exactly are electrons located? Scientists still search for the answers to these questions through the continued study of subatomic particles. During the early 1900s, there was a series of huge developments in science that led to a much deeper understanding of the atom. In the 1920s, the research of scientists such as Louis de Broglie, Erwin Schrodinger, and Wolfgang Pauli led to a profound shift in the way that scientists viewed the atom. The quantum mechanical model was born from their work. While this model may seem complex, it helped explain the electron configurations of an atom. These same electron configurations helped to simplify the periodic table.

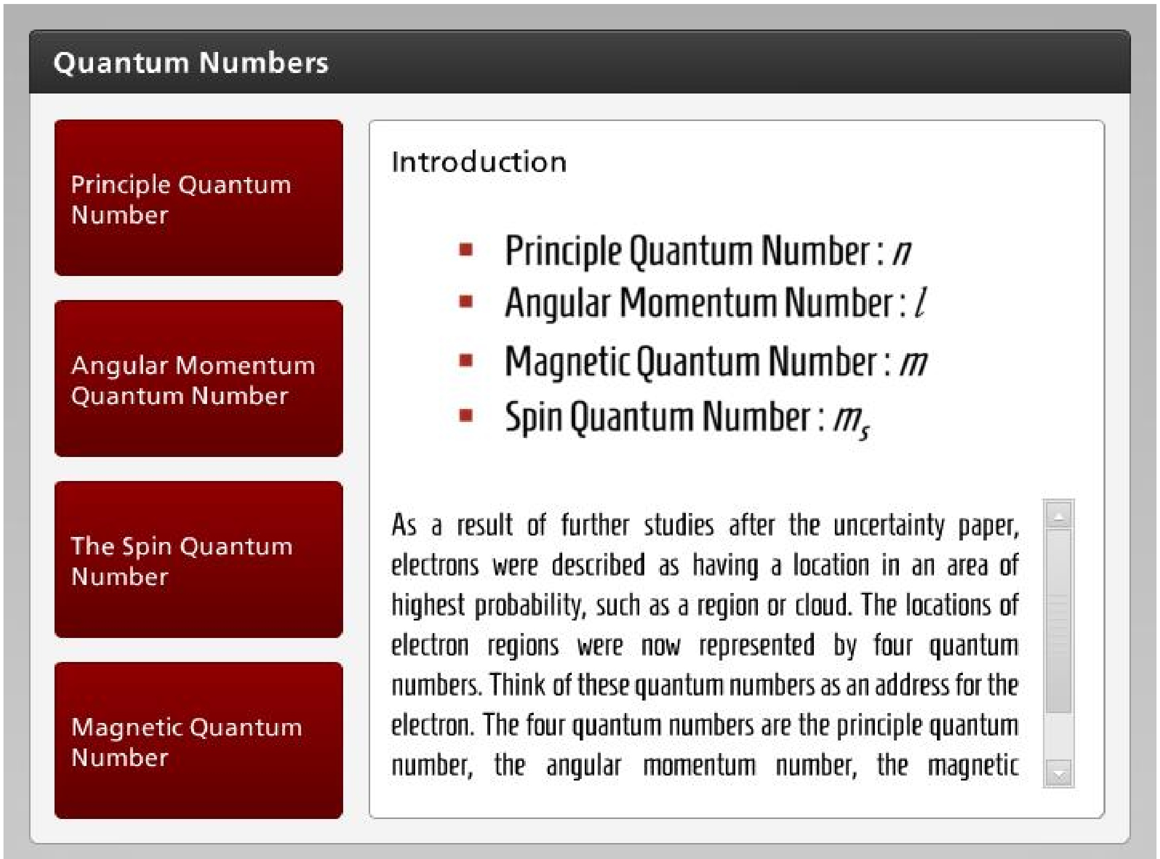


According to the quantum model, electrons do not orbit randomly around the nucleus of the atom. Instead, the electrons occupy specific electron shells, or energy levels, that are subdivided into sublevels. These sublevels contain regions of space called orbitals. This new model fixes the errors in earlier Bohr models. Remember, Bohr described fixed energy levels surrounding the nucleus where electrons were located. In addition, Bohr asserted that electrons move to the next energy level as they absorb a quantum of energy, and that they move to a lower energy level as they lose energy. However, the lowest energy level the electrons could reach was the ground state. He was correct in this observation of quantized electrons; however, he was incorrect in his description of the fixed energy levels.



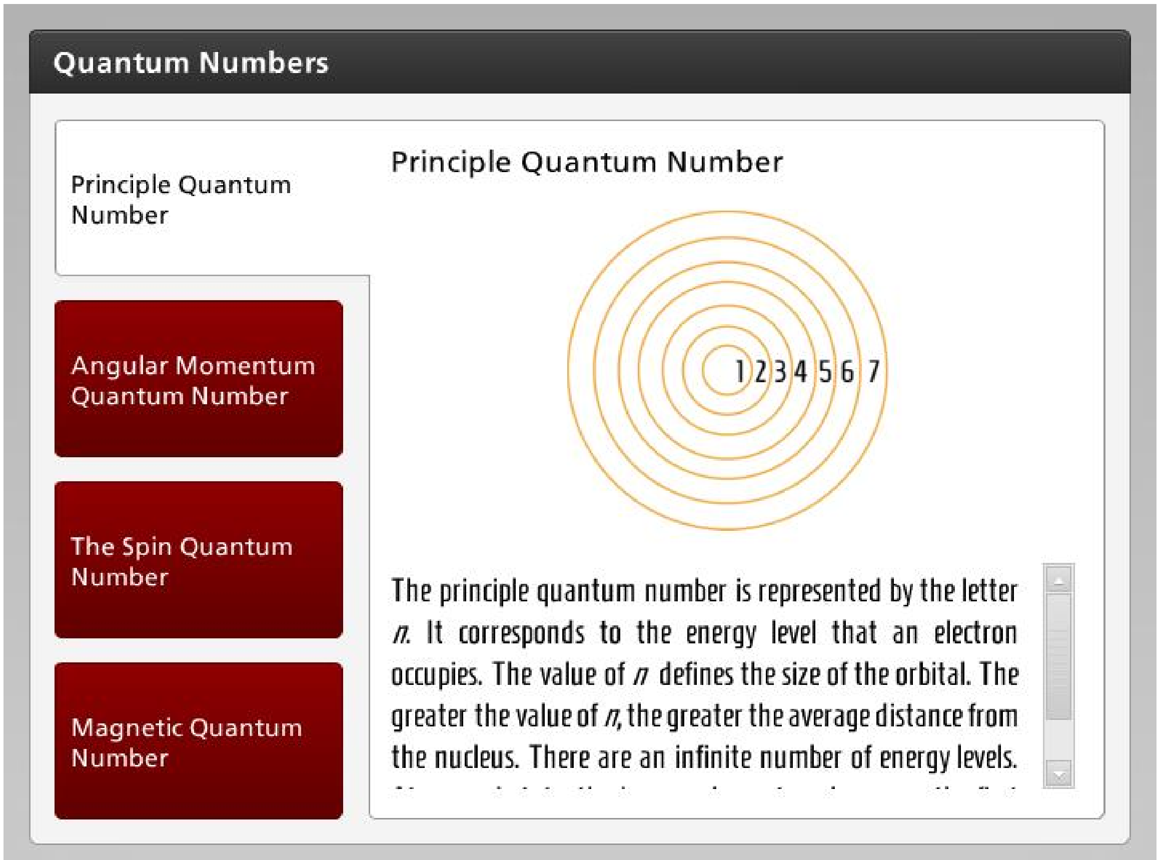
The quantum mechanical model is based on the fact that the exact speed and location of an electron at any given time cannot be determined. The German physicist Werner Heisenberg received the Nobel Prize in physics in 1932 for his work in nuclear physics and quantum theory. The paper on the uncertainty relation is his most important contribution to physics. In Heisenberg's uncertainty paper, he stated that there was an uncertain relationship between the position and momentum of a subatomic particle, such as an electron. This uncertainty made it difficult to locate and define an electron.

Introduction



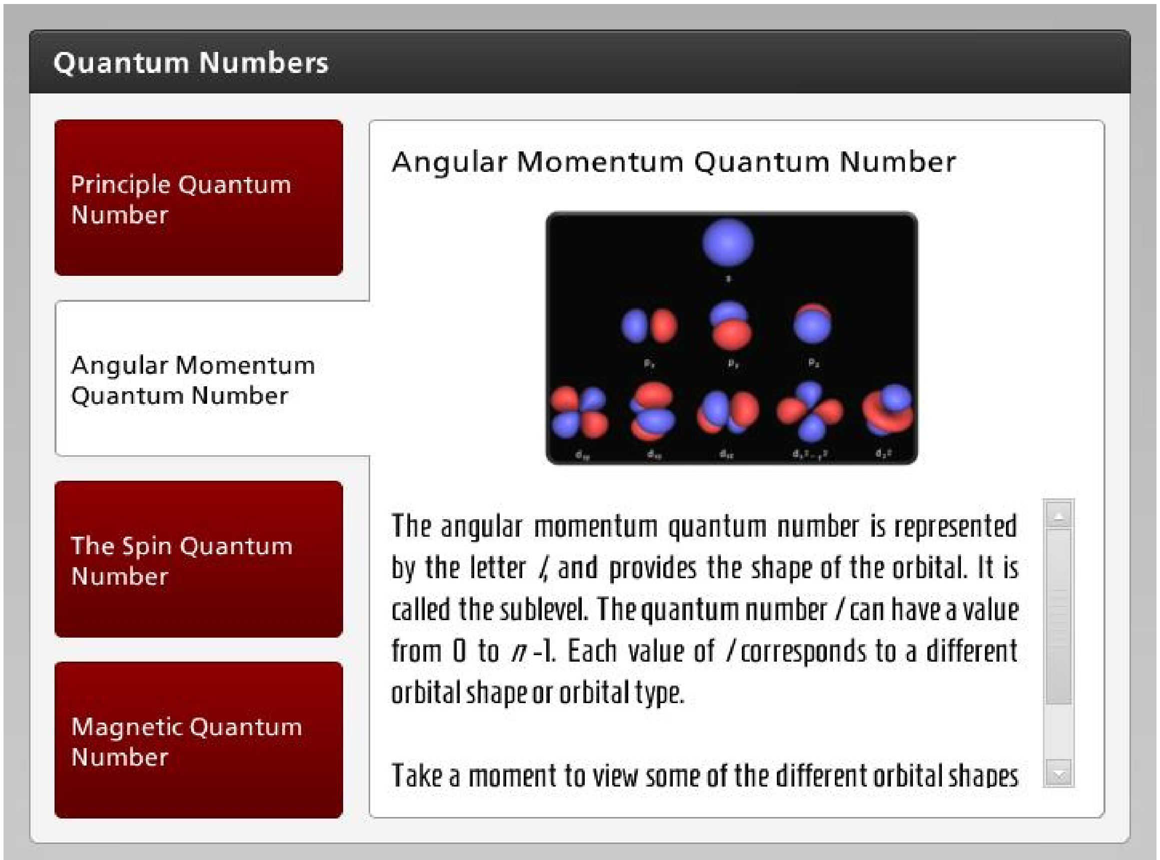
As a result of further studies after the uncertainty paper, electrons were described as having a location in an area of highest probability, such as a region or cloud. The locations of electron regions were now represented by four quantum numbers. Think of these quantum numbers as an address for the electron. The four quantum numbers are the principle quantum number, the angular momentum number, the magnetic quantum number, and the spin quantum number, which are represented by the symbols you see here.

Principle Quantum Number



The principle quantum number is represented by the letter *n*. It corresponds to the energy level that an electron occupies. The value of *n* defines the size of the orbital. The greater the value of *n*, the greater the average distance from the nucleus. There are an infinite number of energy levels. At ground state, the known elements only occupy the first seven levels.

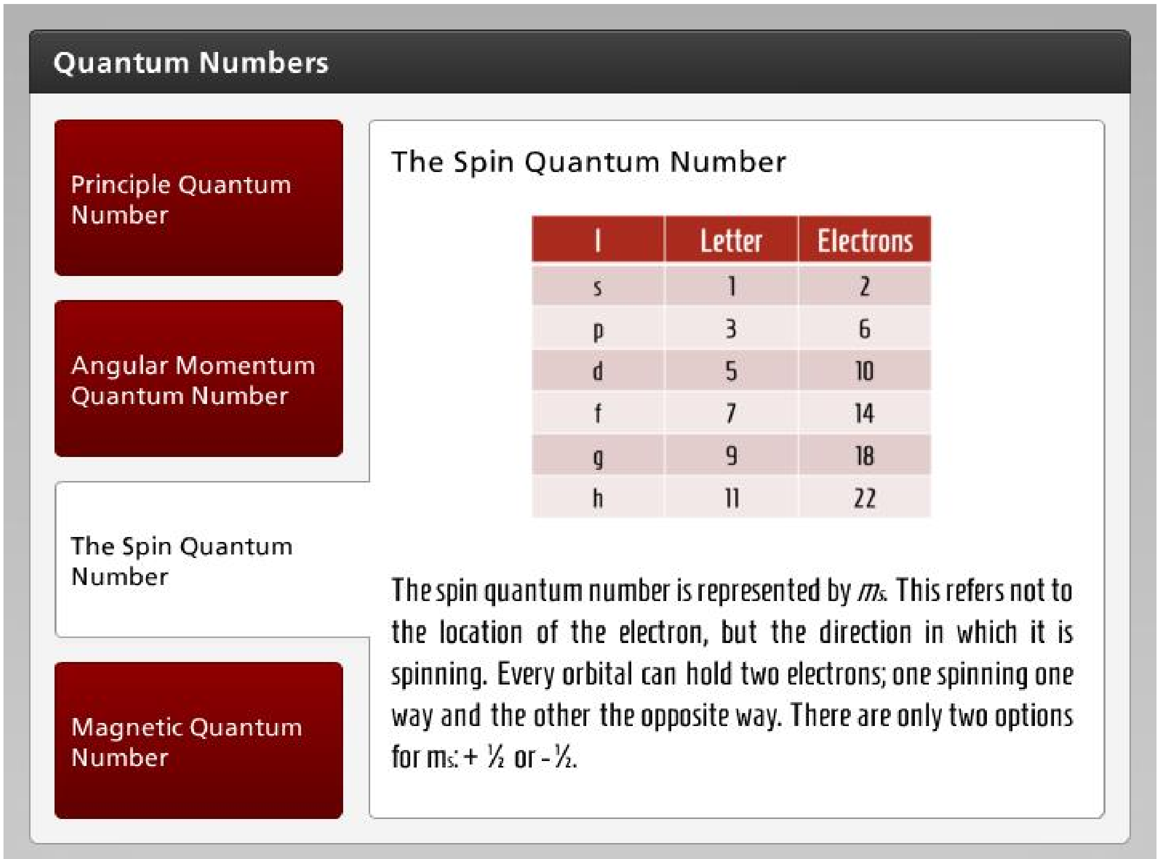
Angular Momentum Quantum Number



The angular momentum quantum number is represented by the letter *l*, and provides the shape of the orbital. It is called the sublevel. The quantum number *l* can have a value from 0 to *n*-1. Each value of *l* corresponds to a different orbital shape or orbital type.

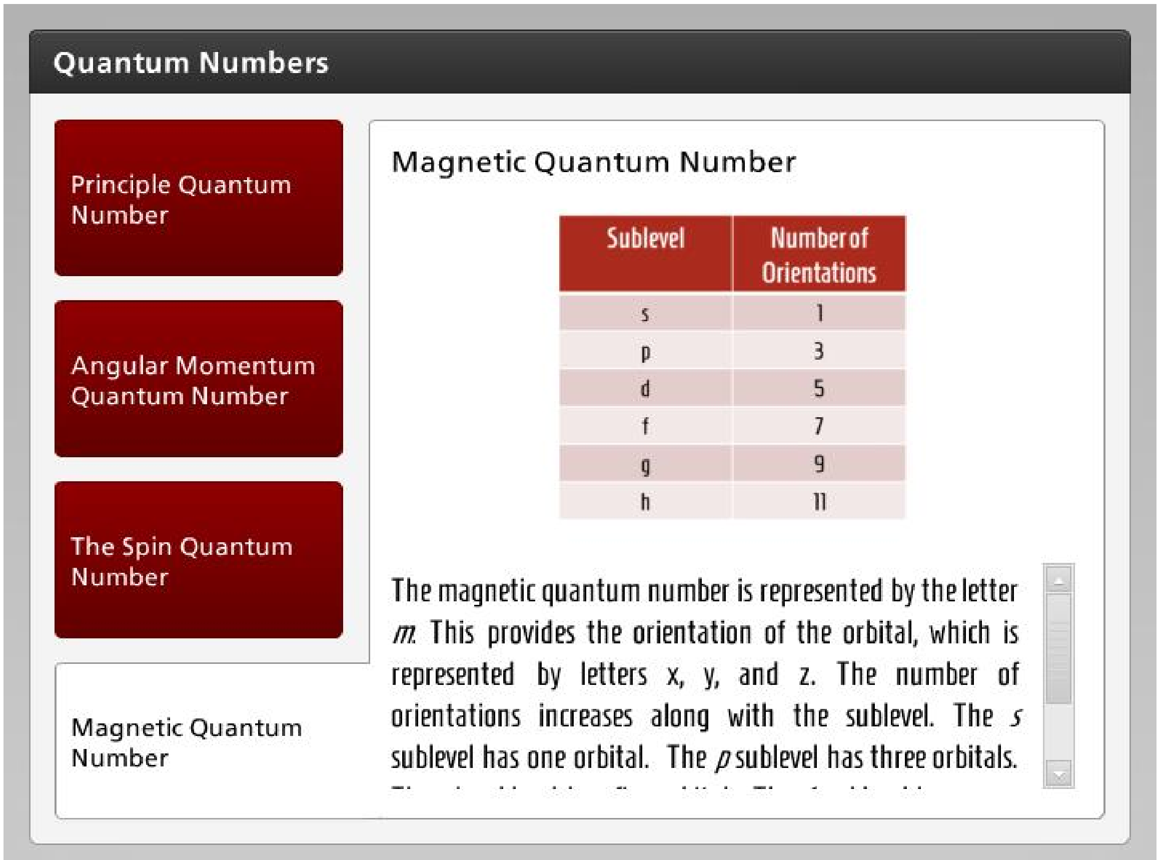
Take a moment to view some of the different orbital shapes including spherical, dumbbell, figure eight, cloverleaf, and top.

The Spin Quantum Number

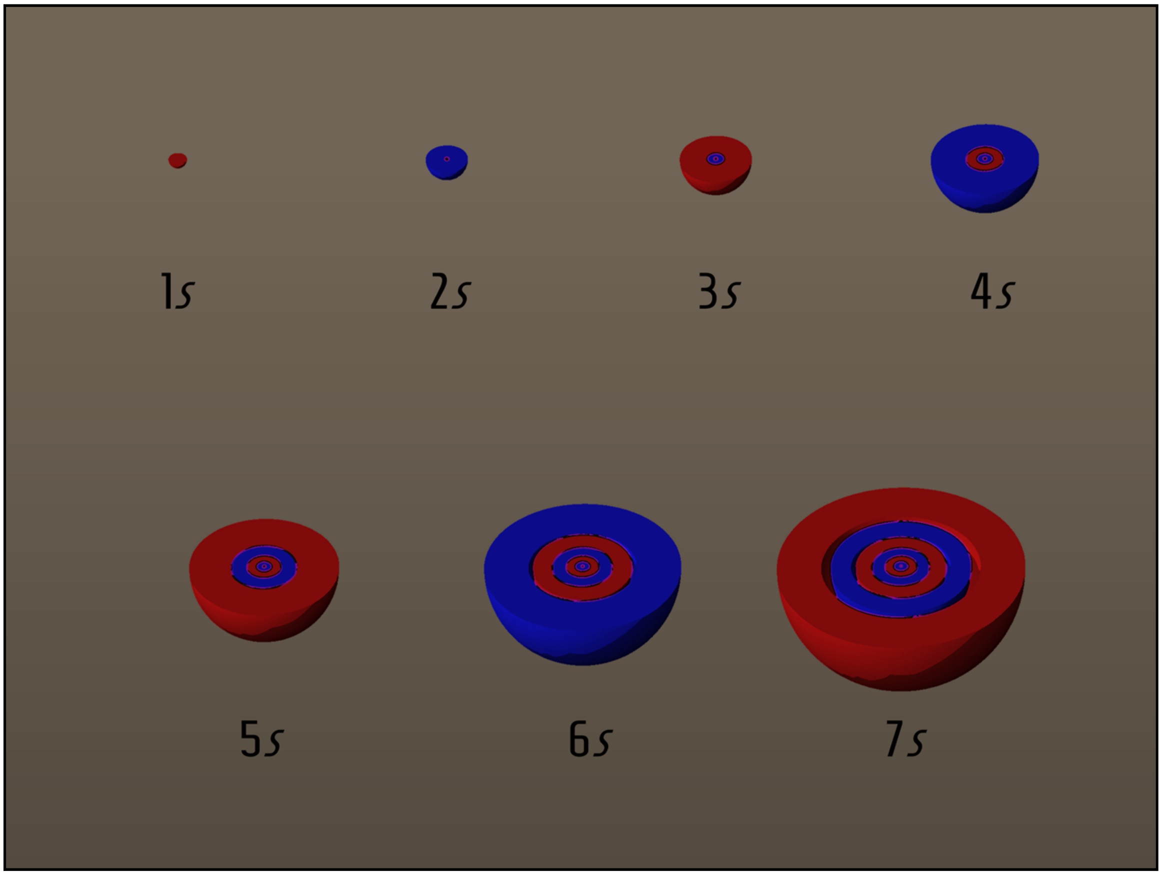


The spin quantum number is represented by m_s. This refers not to the location of the electron, but the direction in which it is spinning. Every orbital can hold two electrons; one spinning one way and the other the opposite way. There are only two options for m_s: + ½ or - ½.

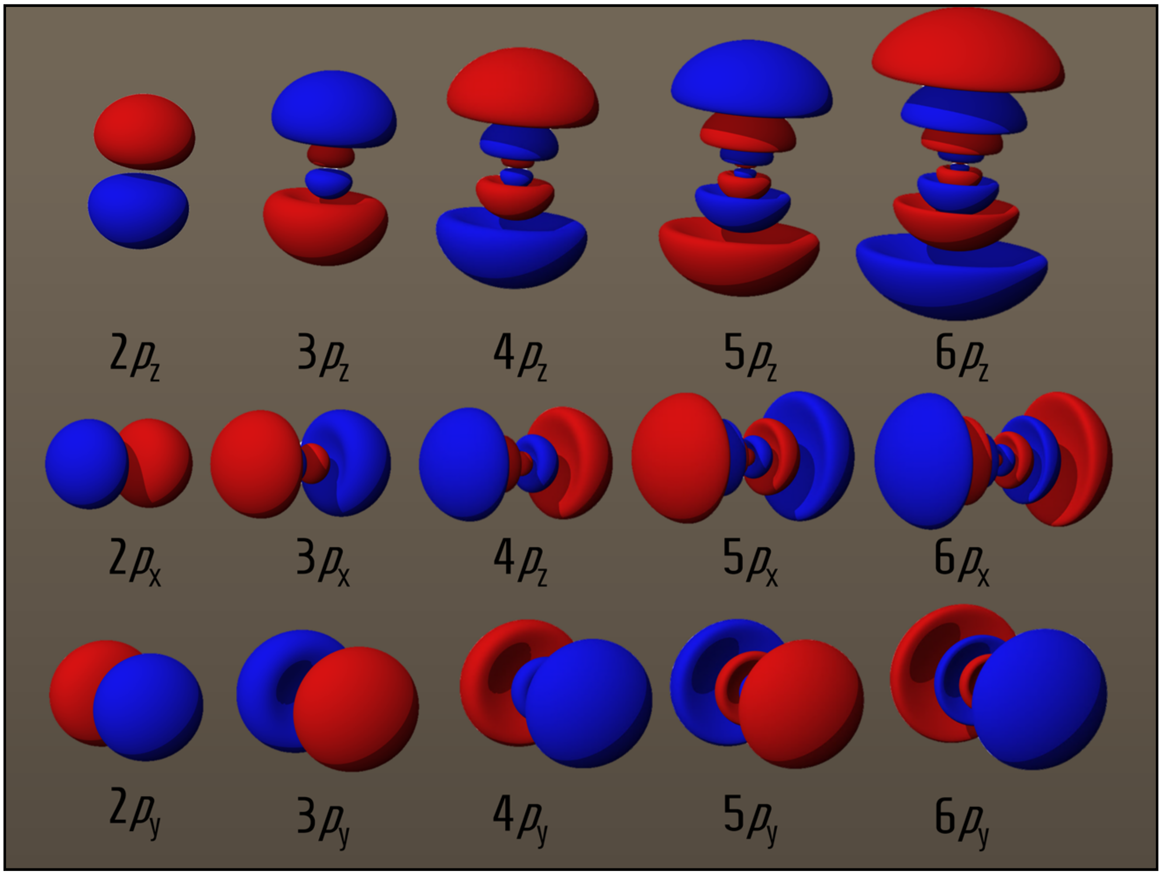
Magnetic Quantum Number



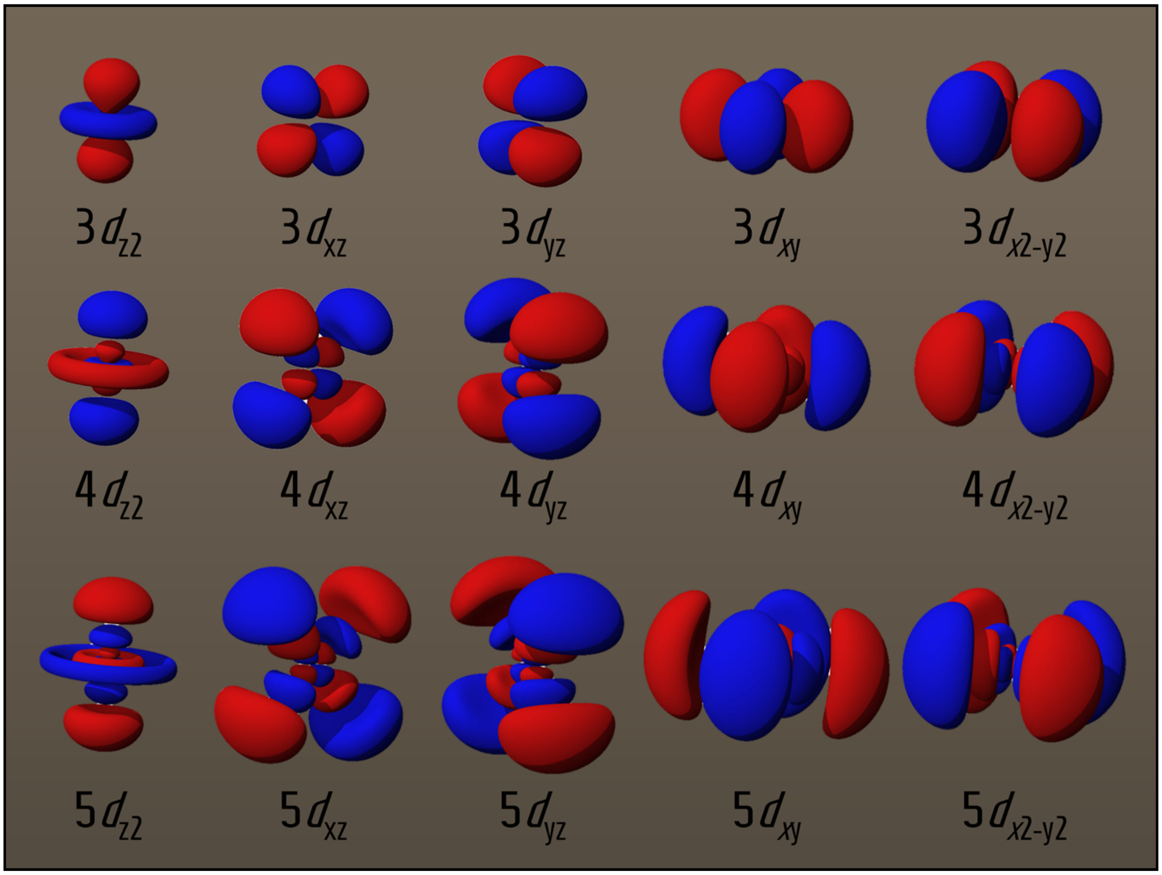
The magnetic quantum number is represented by the letter *m*. This provides the orientation of the orbital, which is represented by letters x, y, and z. The number of orientations increases along with the sublevel. The *s* sublevel has one orbital. The *p* sublevel has three orbitals. The *d* sublevel has five orbitals. The *f* sublevel has seven orbitals. Take a moment to note the pattern of one, three, five, and seven.



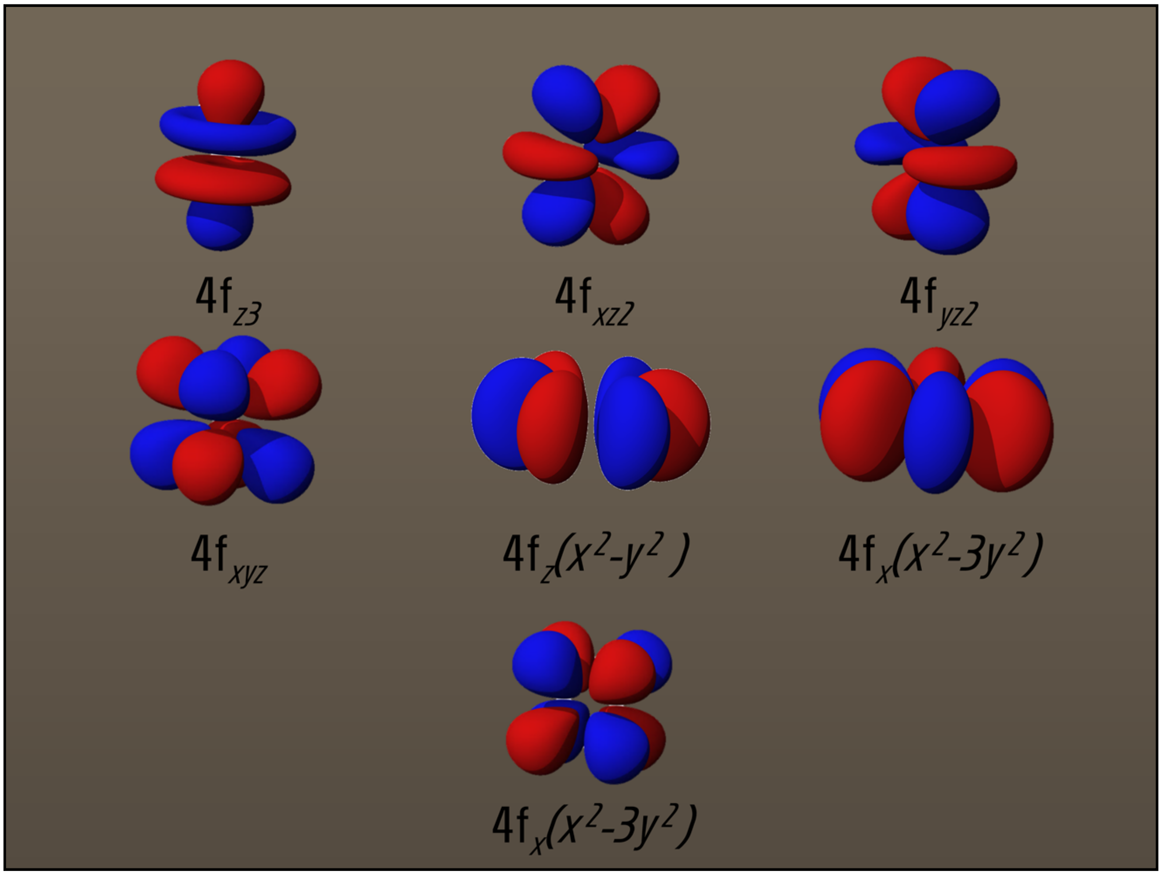
The *s* orbital exists when *l* is equal to zero. The *s* orbital is spherical. Like a basketball, regardless of which way it is turned, it occupies the same space. *S* orbitals only have one orientation. One important difference between *s* orbitals with different *n* values is that the size of *s* orbitals increases as *n* increases. The orbitals for the first seven *n* values are listed 1*s*, 2*s*, 3*s*, 4*s*, 5*s*, 6*s*, and 7*s*.



P orbitals exist when *l* is equal to one. The *p* orbitals all have the same basic shape. They are lobed. When rotated, they do occupy different regions of space. *P* orbitals only have three orientations. They are often called p_x, p_y, and p_z. The *p* orbital is described as a dumbbell shaped as it resembles a weightlifter's dumbbell. Take a moment to view the different shapes found in the *p* orbital.



D orbitals exist when *l* is equal to two. The *d* orbitals are shaped like a four leafed clover. This means that there are four regions of electron density. There are five different orientations. Take a moment to view the different shapes found in the *d* orbital.



F orbitals exist when *l* is equal to three. The *f* orbitals are more complex than the *s*, *p* and *d* orbitals. The shape is like a double four leaf clover. In all of the *f* orbitals, the electron densities are in eight regions of space. There are seven orbitals in an *f* sublevel. Take a moment to view the different shapes found in the *f* orbital.

n	l	ml	Orbitals	Electron Capacity
1	0 (s sublevel)	0	one s orbital	2 total: 2
2	0 (s sublevel)	0	one s orbital	2
	1 (p sublevel)	-1, 0,+1	three p orbitals	6 total: 8
3	0 (s sublevel)	0	one s orbital	2
	1 (p sublevel)	-1, 0,+1	three p orbitals	6
	2 (d sublevel)	-2,-1,0,+1,+2	five d orbitals	10 total: 18
4	0 (s sublevel)	0	one s orbital	2
	1 (p sublevel)	-1, 0,+1	three p orbitals	6
	2 (d sublevel)	-2,-1,0,+1,+2	five d orbitals	10
	3 (f sublevel)	-3,-2,-1,0,+1,+2,+3	seven f orbitals	14 total: 32
5	0 (s sublevel)	0	one s orbital	2
	1 (p sublevel)	-1, 0,+1	three p orbitals	6
	2 (d sublevel)	-2,-1,0,+1,+2	five d orbitals	10
	3 (f sublevel)	-3,-2,-1,0,+1,+2,+3	seven f orbitals	14
	4 (g sublevel)	-4,-3,-2,-1,0,+1,+2,+3,+4	nine g orbitals	18 total: 50
6	0 (s sublevel)	0	one s orbital	2
	1 (p sublevel)	-1, 0,+1	three p orbitals	6
	2 (d sublevel)	-2,-1,0,+1,+2	five d orbitals	10
	3 (f sublevel)	-3,-2,-1,0,+1,+2,+3	seven f orbitals	14
	4 (g sublevel)	-4,-3,-2,-1,0,+1,+2,+3,+4	nine g orbitals	18
	5 (h sublevel)	-5,-4,-3,-2,-1,0,+1,+2,+3,+4,+5	eleven h orbitals	22 total: 72

The energy levels, or subshells, are also organized to include the number of orbitals that each contains. The first electron shell, or energy level one, only has the *s* sublevel. The second electron shell, or energy level two, contains both the *s* and *p* sublevels. The third electron shell, or energy level, contains the *s, p* and *d* sublevels. The fourth electron shell contains the *s, p, d,* and *f* sublevels. The pattern suggests that the fifth energy level would have the *s, p, d, f* and *g* sublevels.

This means that the first energy level has only one orbital in *s* sublevel. The second energy level has one orbital in the *s* sublevel and three in the *p* sublevel. The third energy level has one in the *s* , three in the *p* sublevel and five in the *d* sublevel. The fourth energy level has one orbital in the *s* sublevel, three in the *p* sublevel, five in the *d* sublevel and seven in the *f* sublevel. This pattern continues, but for the known elements, the sublevels are only occupied up to energy level seven, sublevel *p*. Take a moment to view the chart that summarizes the orbitals proposed by the quantum mechanical model. Those in italicized font are only theoretical and have not been established with experimental evidence.