Activity 8 Name
Atomic Theory Part I: Quantum Numbers

The quantum numbers are determined from the mathematical determination of structure of the atom. The quantum number, *n*, represents the energy level and the distance from the center of the atom. *n* can only be whole number beginning with 1. The second quantum number, ℓ, most closely represents the orbital in which the electron moves. This number is dependent upon the energy level and can be any integer between zero and *n* minus 1. These quantum numbers are also closely associated with the orbitals, s, p, d, f, g, h, i, etc. The third quantum number, m_l, represents the actual path with directionality (x, y, z) and can only have integers values from $-\ell$ to $+\ell$ The last quantum number, m_s, can only be + ½ or – ½ . This quantum number best describes the movement of the electron in the orbital.

n value	ℓ value	m_l value	m_s value	Orbital representation	Number of electron in orbital
n = 1, 2, …∞	ℓ = 0, 1, ..*n*-1	m_l = 0, ±1, ±ℓ	m_s = ±½	s, p, d, f, g, h, i, j, …	One for each set of 4 quantum numbers
n = 1	ℓ = 0	m_l = 0	m_s = +½ and -½	1s	2 electrons
n = 2	ℓ = 0	m_l = 0	m_s = +½ and -½	2s	2 e^-
	ℓ = 1	m_l = +1	m_s = +½ and -½	$2p_x$, $2p_y$, $2p_z$ } 2p	2 + 2 + 2 } = 6 e^-
		m_l = 0	m_s = +½ and -½		
		m_l = -1	m_s = +½ and -½		
n = 3	ℓ = 0	m_l = 0	m_s = ±½	3s	2 e^-
	ℓ = 1	m_l = +1	m_s = ±½	3p	6 e^-
		m_l = 0	m_s = ±½		
		m_l = -1	m_s = ±½		
	ℓ = 2	m_l = +2	m_s = ±½	3d	10 e^-
		m_l = +1	m_s = ±½		
		m_l = 0	m_s = ±½		
		m_l = -1	m_s = ±½		
		m_l = -2	m_s = ±½		

	Input all possible ℓ values	m_l values for each ℓ value.	Input the possible m_s values for each m_l value	orbital designations	Number of electrons in orbital
n = 6	*0*	0	m_s = ±½	6s	2 e^-
	1	+1 0 -1	m_s = ±½	6p	6 e^-
	2	+2 +1 0 -1 -2	m_s = ±½	6d	10 e^-
	3	+3 +2 +1 0 -1 -2 -3	m_s = ±½	6f	14 e^-
	4	+4 +3 +2 +1 0 -1 -2 -3 -4	m_s = ±½	6g	18 e^-
	5	+5+4+3+2+10-1-2-3-4-5	m_s = ±½	6h	22 e^-

Problems:

1. What are the possible ℓ and m_l values for the quantum number *n* = 8?
   ℓ = 0 with m_l = 0;

ℓ = 1 with m_l = +1, 0, -1;
ℓ = 2 with m_l = +2, +1, 0, -1, -2
ℓ = 3 with m_l = +3, +2, +1, 0, -1, -2, -3;
ℓ = 4 with m_l = +4, +3, +2, +1, 0, -1, -2, -3, -4;
ℓ = 5 with m_l = +5, +4, +3, +2, +1, 0, -1, -2, -3, -4, -5;
ℓ = 6 with m_l = +6, +5, +4, +3, +2, +1, 0, -1, -2, -3, -4, -5, -6
ℓ = 7 with m_l = +7, +6, +5, +4, +3, +2, +1, 0, -1, -2, -3, -4, -5, -6, -7

2. Explain why each of the following sets of quantum numbers would be allowed or not allowed.
   a) $n = 4$; $\ell = 3$; $m_l = 0$; $m_s = +½$ allowed
   b) $n = 5$; $\ell = 0$; $m_l = 0$; $m_s = 0$ not allowed - m_s cannot be 0
   c) $n = 11$; $\ell = 10$; $m_l = -8$; $m_s = +½$ allowed
   d) $n = 9$; $\ell = 9$; $m_l = 0$; $m_s = -½$ not allowed - ℓ cannot equal n

The quantum numbers allow us to determine how many electrons and where they are most likely to be in the structure of the possible orbitals. As the value of *n* increases, the possible number of sub energy levels or orbitals increases and the number of pathways in which the electrons reside increases. Therefore with each value of *n*, we add a new orbital designation and the number of electrons that can reside in each orbital type increases.

ℓ value	0	1	2	3	4	5	6	7
Orbital designation	*ns*	*n*p	*n*d	*n*f	*ng*	*n*h	*n*i	*n*j
Number of electrons	*2*	*6*	*10*	*14*	*18*	*22*	*26*	*30*

Therefore we can show this increase in number of orbitals as

1s							
2s	2p						
3s	3p	3d					
4s	4p	4d	4f				
5s	5p	5d	5f	5g			
6s	6p	6d	6f	6g	6h		
7s	7p	7d	7f	7g	7h	7i	
8s	8p	8d	8f	8g	8h	8i	8j

Where the *s* orbital can hold only 2 electrons, the *p* orbital can hold 6 electrons, *d* 10 electrons; *f* 14 electrons; *g* 18 electrons, etc.

3. How many possible electrons can be held in the *n* = 8 energy level?

Number of electrons	*2*	*6*	*10*	*14*	*18*	*22*	*26*	*30*

= sum of 128 electrons

Activity 8 Name Atomic Theory

Part II: Atomic Structure and Electron Configurations

1. Fill in the following table. The atomic number of the element represents the number of protons held in the nucleus of the atom and in neutral atoms the positive charge of the protons is equal and opposite to the negative charge of the electrons. The periodic table is set up in columns and rows. Count the rows down beginning at the top and the columns or blocks across beginning at the left. Where is the element located?

Symbol	Number of protons	Total Number of electrons	Number of Valence Electrons	In which row is the element located?	In which column is the element located?
${}^{1}_{1}H$	1	1	1	1	1st column from the left
${}^{7}_{3}Li$	3	3	1	2	First column in row
${}^{14}_{7}N$	7	7	5	2	5th column from the left in row
${}^{40}_{18}Ar$	18	18	8	3	Eighth column on row
${}^{112}Cd$	48	48	12	5	12 column in row
${}^{40}K$	19	19	1	4	First column in row
${}^{40}K^{1+}$	19	18			
${}^{16}O$	8	8	2	6	6 column in row
${}^{16}O^{2-}$	8	10			
${}^{238}U$	92	92	6	7	6th column in row

2. What conclusion can you make about the column position of the element on the periodic table and the number of valence electrons?

   The number of valence electrons is similar to the number of columns that are counted from the left (first column) until the element is reached in its row.

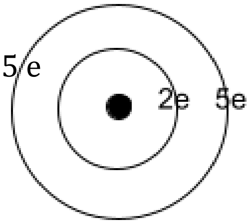
3. Draw the Bohr atom model for the following atoms or ions. The Bohr atom puts electrons into orbits that build outward from the nucleus of the atom. The orbit closest to the nucleus is called the ground state; all other orbits are called excited states. The orbit that is farthest from the nucleus but still contains electrons is called the valence shell or orbit. Each row on the periodic table basically represents an energy level, while the columns or blocks in each row represent the number of electrons within that energy level. Therefore, for Nitrogen in the second row has two orbits and 2 block or columns in the first row represent two electrons, 5 blocks or columns in the second row represent 5 electrons.

   a) H atom Nucleus 1e

   b) Li atom Nucleus 2 e 1 e

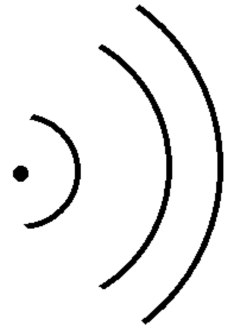
c) N atom

Nucleus 2 e 5 e



d) Ar

Nucleus 2e 8 e 8 e



e) Cd

Nucleus 2 8 8 18 12

f) K

Nucleus 2 8 8 1

g) O

Nucleus 2 6

h) K^{+1}

Nucleus 2 8 8 0

i) O^{2-}

Nucleus 2 8

j) U

Nucleus 2 8 8 18 18 32 6

4. Indicate the energy levels and the energy levels for the following atoms. Given the drawings above, each ring represents the orbits or energy levels. The first ring is n = 1, second ring is n = 2, third ring is n = 3, etc. This is just a written description of the Bohr model.

c) N atom
n = 1 with 2 electrons
n = 2 with 5 electrons

e) Cd
n = 1 with 2 electrons
n = 2 with 8 electrons
n = 3 with 8 electrons
n = 4 with 18 electrons
n = 5 with 12 electrons

5. The Quantum model of the atom adds complexity to the structure of the atom. The orbits or energy levels are separated into sub energy level or orbitals with the designations: s, p, d and f. Label or color the areas on the Periodic table with the correct orbital designations. Notice the first row has both blocks represented on the left rather than split.

	1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
n=1	1s	1s																
n=2	2s												2p	2p	2p	2p	2p	2p
n=3	3s												3p					
n=4	4s		3d	3d	3d	3d	3d	3d	3d	3d	3d	3d	4p					
n=5	5s		4d										5p					
n=6	6s		5d										6p					
n=7	7s		6d										7p					

4f	4f	4f	4f	4f	4f	4f	4f	4f	4f	4f	4f	4f	4f
5f													

6. Indicate the number of electrons present in each energy sublevel or orbitals of the above atoms. For example, Nitrogen has 7 electrons, 2 in the first row and 5 in the second row. In the first row (period), the two blocks (columns) are in the s orbital, which is the only orbital that exists in n = 1. In the second row (period), the columns are split into two separate blocks, the first two columns are in the s block while the last 6 columns are in the p block for which only 3 columns are filled for nitrogen representing 3 electrons in the p orbital. This is indicated in the example below.

c) N atom

In n = 1, there are 2 electrons in the s orbital

In n = 2, there are 2 electrons in the s orbital and 3 electrons in the p orbital

e) Cd

n = 1 with 2 electrons in the s orbital

n = 2, 2 electrons in the s orbital and 6 electrons in the p orbitals

n = 3, 2 electrons in the s orbital and 6 electrons in the p orbitals

n = 4, 2 electrons in s orbital, 10 in d orbitals and 6 electrons in p orbitals

n = 5, 2 electrons in s orbital, 10 in d orbitals

j) U

n = 1 with 2 electrons in the s orbital

n = 2, 2 electrons in the s orbital and 6 electrons in the p orbitals

n = 3, 2 electrons in the s orbital and 6 electrons in the p orbitals

n = 4, 2 electrons in s orbital, 10 in d orbitals and 6 electrons in p orbitals

n = 5, 2 electrons in s orbital, 10 in d orbitals and 6 electrons in p orbitals

n = 6, 2 electrons in s orbital, 14 in f orbitals, 10 in d orbitals and 6 electrons in p orbitals

n = 7, 2 electrons in s orbital, 4 electrons in orbitals

7. The electron configuration is a shorthand for the above information to indicate the number and location of each electron in an atom. The short hand designation includes the energy level (*n* =), the orbital designation (s, p, d or f) and a superscript indicating the exact number of electrons in the orbital or sublevel. So for Nitrogen, in *n* = 1, there are two electrons in the s orbital, which is written as $1s^2$. The problem arises when we reach the 4th period or energy level. We have to finish filling the third period orbitals, the 3d, which fills after the 4s has filled completely. A similar problem arises with the f orbital designations. Write the electron configuration of each of the following:

a) H atom $1s^1$

b) Li atom
$1s^2 2s^1$

c) N atom
$1s^2 2s^2 2p^3$

d) Ar
$1s^2 2s^2 2p^6 3s^2 3p^6$

e) Cd
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10}$

f) K
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

g) O
$1s^2 2s^2 2p^4$

h) K^{+1}
$1s^2 2s^2 2p^6 3s^2 3p^6$

i) O^{2-}
$1s^2 2s^2 2p^6$

j) U
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$
$5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^4$

8. Given the following electron configurations, indicate which atom on the periodic table it represents.

a) $1s^2$
Helium

b) $1s^2 2s^2 2p^3$
nitrogen

c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$
As - Arsenic

d) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^5$
Tc - Technetium

e) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^3$
Bi - Bismuth

f) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^1 5f^{14}$
Md - Mendelevium