Electron Configurations

Arranging the Electrons by the Quantum Mechanical Model

Placing the Electrons

The location of electrons follows certain rules or principles:

- The ***Aufbau Principle*** – electrons fill orbitals starting at the lowest available energy state before filling higher states.
- ***Hund's Rule*** – unoccupied orbitals of a given energy will be filled before occupied orbitals of the same energy are reused. (like seats on a bus)
- The ***Pauli Exclusion Principle*** – no two electrons in an atom can occupy the same quantum state. (be in the same orbital ***and*** have the same spin)
  - An orbital can hold a maximum of two electrons

PATTERNS

- The first energy level has only one sublevel, s; the second energy level has two sublevels, s and p; the third energy level has three sublevels, s, p, and, d; and so on.
- There is 1 s orbital, 3 p orbitals, 5 d orbitals, 7 f orbitals, and so on.
- There are a maximum of two electrons per orbital.
- Using this information, can you fill in the table below?

Principal Energy Level (n)		Number of Orbitals (n^2)	Electrons per Sublevel							Maximum Number of Electrons ($2n^2$)
			s	p	d	f	g	h	i	
			1	3	5	7	9	11	13	
Electrons in Each Location	1	1	2	–	–	–	–	–	–	2
	2	4	2	6	–	–	–	–	–	8
	3	9	2	6	10	–	–	–	–	18
	4	16	2	6	10	14	–	–	–	32
	5	25	2	6	10	14	18	–	–	(50)
	6	36	2	6	10	14	18	22	–	(72)
	7	49	2	6	10	14	18	22	26	(98)

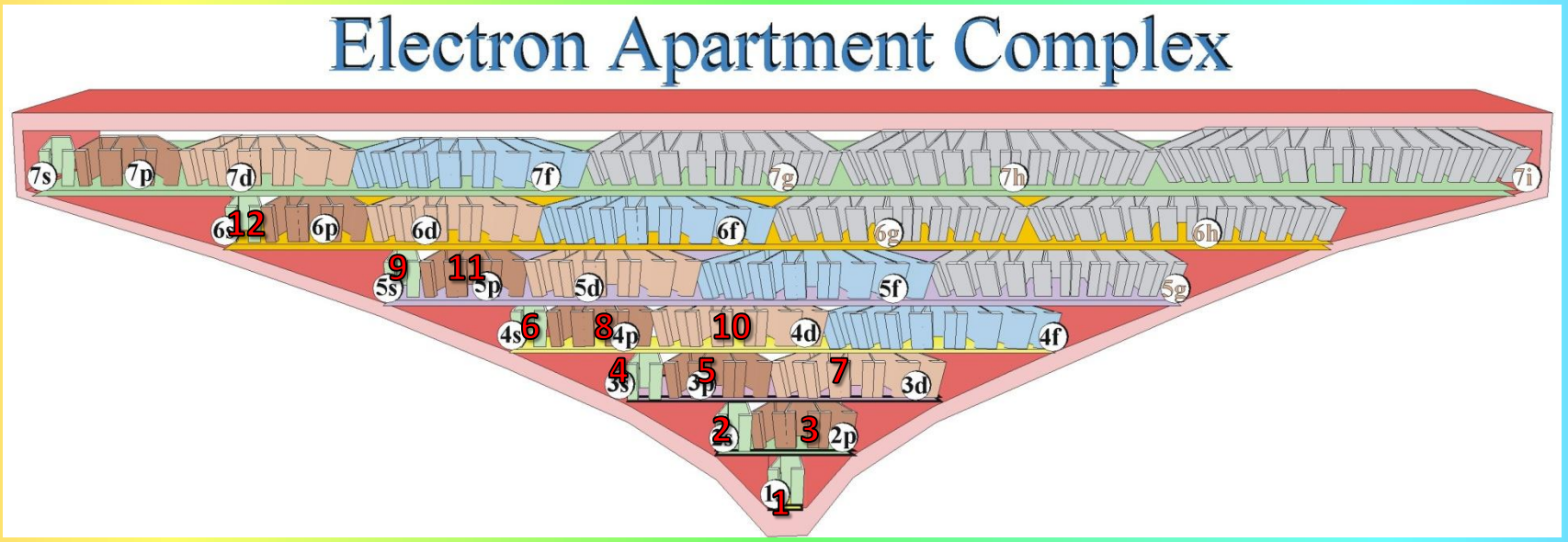
AN ANALOGY

Sometimes it is helpful to think of the atom as an apartment house.

- Each *floor* is like an **energy level**. (1-7)
- Each *apartment* is like a **sublevel**. (*s*, *p*, *d*, or *f*)
  - Higher energy levels are larger, so they have more sublevels
    - ❑The first level (floor) has one sublevel (apartment) – *s*
    - ❑The second has two – *s* and *p*
    - ❑And so on
- Each *bedroom* is like an **orbital**.
  - "*s*" apartments have *one* bedroom
  - "*p*" apartments have *three* bedrooms
  - "*d*" apartments have *five* bedrooms, and
  - "*f*" apartments have *seven* bedrooms

EXPANDING THE ANALOGY

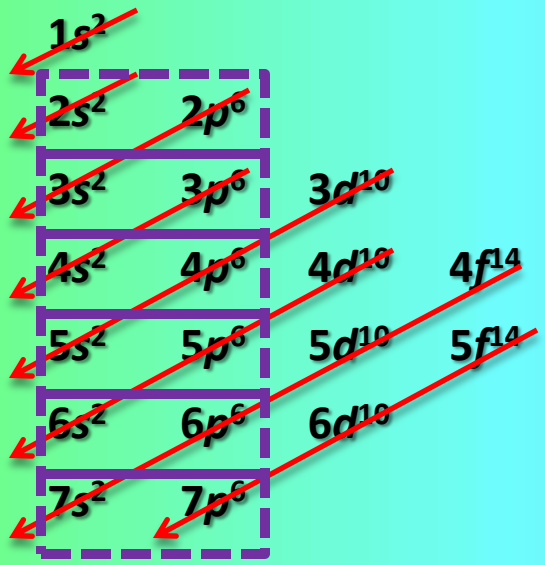
- Imagine electrons are moving into the apartment complex pictured below:
  - Electrons don't like to waste energy climbing to apartments on higher floors.
  - Electrons don't like to waste energy caring for larger apartments.
  - Electrons move into the most energy efficient apartments first.



- In what order do the apartments fill up?

ORDER OF FILLING

- The electrons are arranged according to the following rules:
  - the number of electrons equals the number of protons (atomic number)
  - electrons occupy orbitals in sequence beginning with those of the lowest energy.
  - in a given sublevel, a second electron is not added to an orbital until each orbital in the sublevel contains one electron.



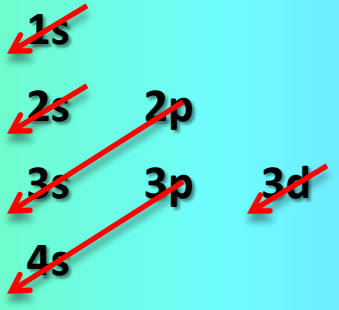
- One consequence of the order of filling is that an outer shell never has more than eight electrons.

A Sample Electron Configuration

- Consider the element scandium shown below:

44.9559	+3
Sc	
21	
2-8-9-2	

- What do the rules for the order of filling show about the electron configuration?
  - First 1*s* fills with 2 electrons leaving 19
  - Second 2*s* fills with 2 electrons leaving 17
  - Next 2*p* fills with 6 electrons followed by 3*s* with 2 electrons leaving 9
  - Then 3*p* fills with 6 electrons followed by 4*s* with 2 electrons leaving 1
  - Finally the remaining electron goes into 3*d*



- This gives an electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$.

Types of Electron Configurations

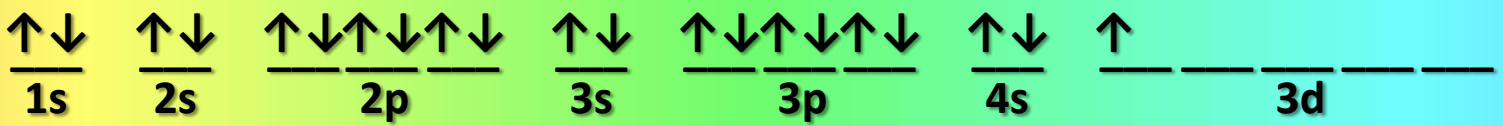
- ***Sublevel Notation***: sublevel notation shows how many electrons are in each sublevel

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

- ***Bohr Notation***: Bohr notation shows the number of electrons in each shell or energy level

2 – 8 – 9 – 2

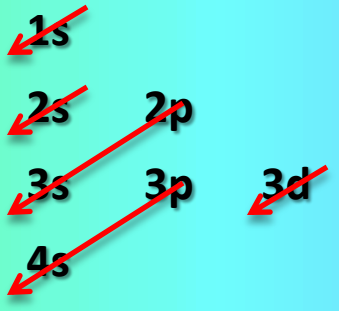
- ***Orbital Notation***: Orbital notation shows the electrons and their spin in each orbital



More on Orbital Notation

Drawing the Orbital Notation for Iron (Atomic Number = 26)

- **Step 1**: Determine the sublevel notation of iron
  - 1*s* has room for 2 electrons, leaving 24.
  - 2*s* has room for 2 electrons, leaving 22.
  - 2*p* has room for 6 electrons and 3*s* has room for 2 more, leaving 14.
  - 3*p* has room for 6 electrons and 4*s* has room for 2 more, leaving 6.
  - 3*d* has room for the remaining 6
  - The electron configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$.

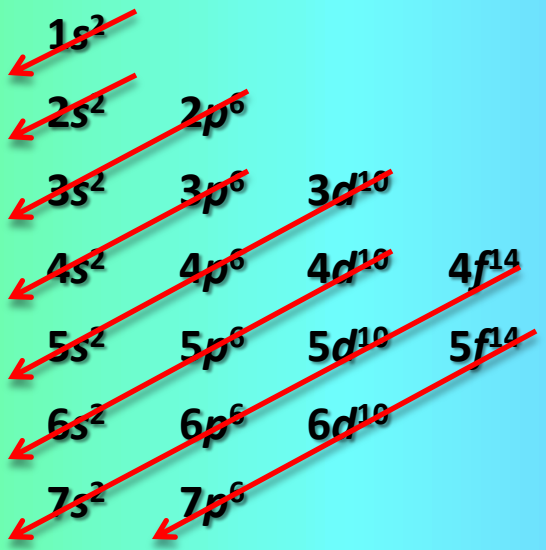


- **Step 2**: Use the information from the sublevel notation to draw the orbital notation
  - Draw a horizontal line to represent each orbital in a sublevel, and label it.
  - Add one electron at a time to each orbital, represented by an up or down arrow, in the same order as in the sublevel notation.
    - ❖ Electrons in an orbital must have opposite spins (arrows in opposite directions).
    - ❖ Follow Hund's rule. Do not begin pairing electrons in an orbital until all the orbitals in a sublevel have an electron

SUMMARY

- Draw the sublevel notation by following the order of filling.

Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$



- Draw the Bohr notation by adding together all the electrons in the same energy level.

Fe: 2-8-14-2

- Draw the orbital notation by taking the information from the sublevel notation.

Fe: ↑↓ (1s) ↑↓ (2s) ↑↓ ↑↓ ↑↓ (2p) ↑↓ (3s) ↑↓ ↑↓ ↑↓ (3p) ↑↓ (4s) ↑↓ ↑ ↑ ↑ ↑ (3d)