Atomic Models

The Bohr Model

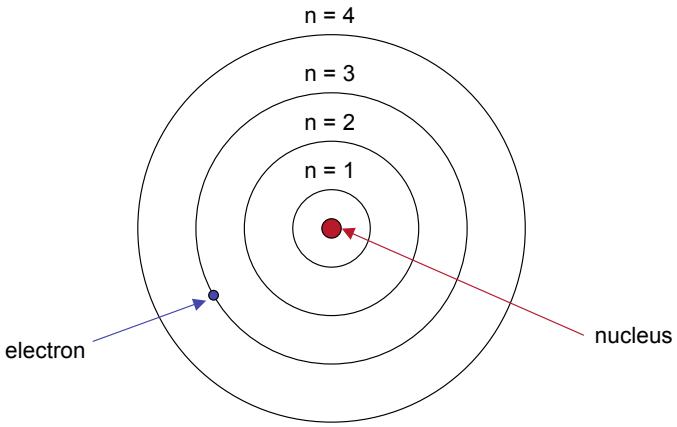
Electrons in an atom can only exist in certain energy levels

The energy of the electron is said to be "quantized".

Analogous to rungs of a ladder where the rungs need not be equally spaced.

Bohr Model of the Atom

The specific energy level of the electron is denoted by the "principal quantum number: n"



Bohr Model of the Atom

Bohr's model of the atom described the observed behavior of the hydrogen atom, but could not adequately explain behavior of other elements like helium, lithium, or any other of the larger atoms.

The atomic model of the atom was developed to describe all observed characteristics of atoms.

Atomic Model of the Atom

- Electrons reside in "orbitals" surrounding the nucleus of the atom.
- There are four types of electron orbitals: s, p, d, and f.

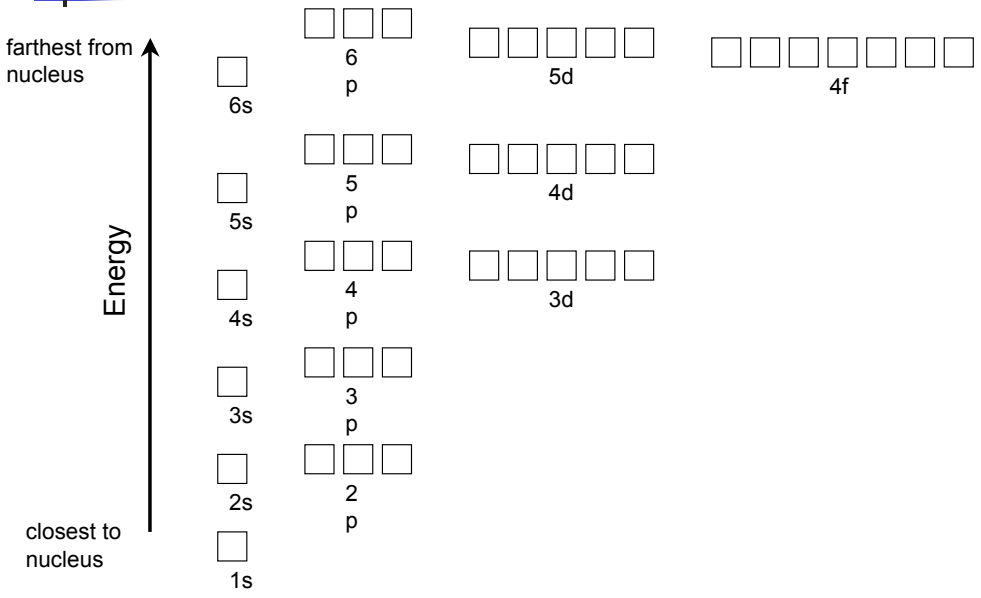
An orbital describes the probability of finding the electron at a certain location around the nucleus. A picture of the shapes of the different orbitals is found on page 149 of the textbook.

Atomic Model of the Atom

- There is one s orbital per principal quantum number, n—spherical in shape
- There are three p orbitals per principal quantum number, n = 2 or higher
- There are five d orbitals per principal quantum number, n = 3 or higher
- There are seven f orbitals per principal quantum number, n = 4 or higher

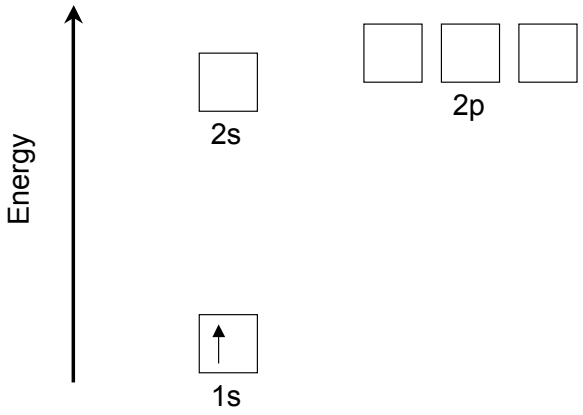
Each orbital may hold only two electrons.

Energy levels of atomic orbitals



Placement of Electrons in Atomic Orbitals
(remember e^-'s go into lowest energy orbital available)

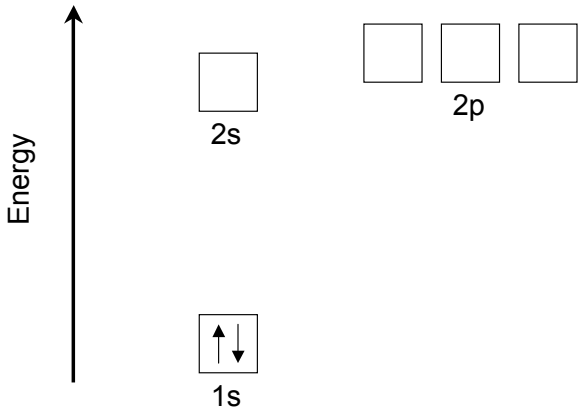
Hydrogen (H): 1 electron



Lowest energy orbital available is the 1s orbital.

Placement of Electrons in Atomic Orbitals
(remember e^-'s go into lowest energy orbital available)

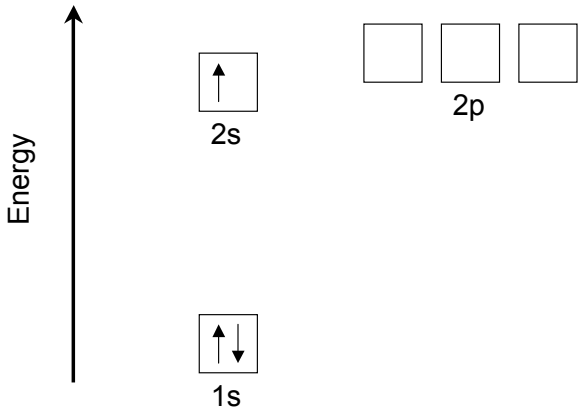
Helium (He): 2 electrons



2nd electron pairs with the first in the 1s orbital. This completes the n=1 principal quantum number shell.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

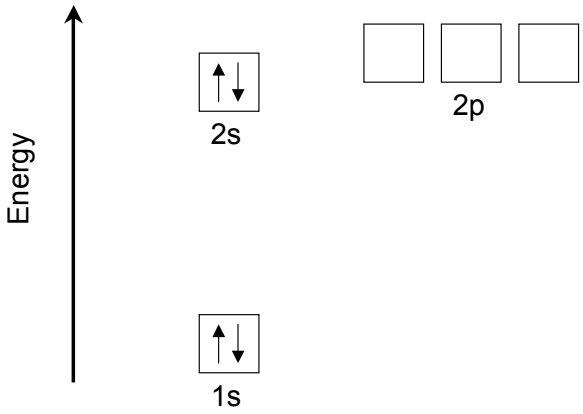
Lithium (Li): 3 electrons



3rd electron cannot go into 1s orbital because it is full (orbitals may hold only two electrons). It goes into the 2s orbital because that is the next lowest energy orbital available.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

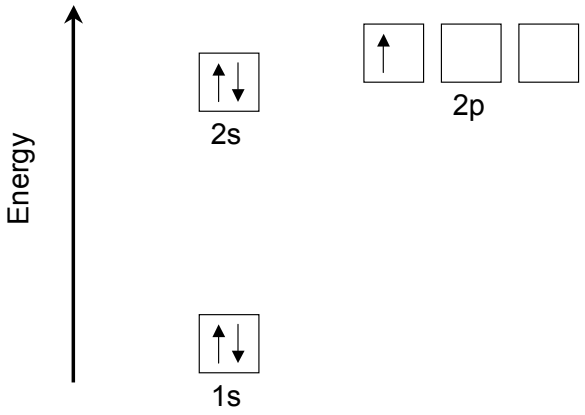
Beryllium (Be): 4 electrons



Electrons prefer not to pair up if possible because their negative charges repel each other. 4th electron pairs with the 3rd electron in the 2s orbital because the 2p orbitals are higher in energy than the 2s.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

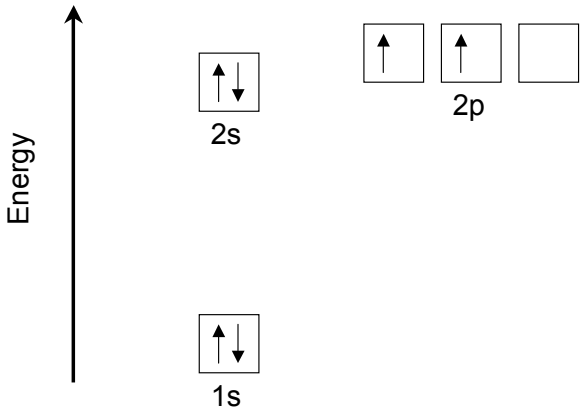
Boron (B): 5 electrons



5th electron goes into the 2p orbitals because the lower energy 2s orbital is full. The next orbitals available are the 2p's.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

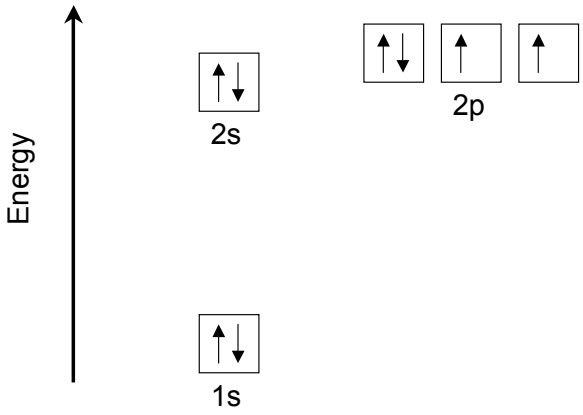
Carbon (C): 6 electrons



The 6th electron could either pair with the 5th e⁻ in the first 2p orbital or go into the next 2p orbital. However, e⁻'s prefer to be unpaired if possible, so this e⁻ chooses the next available 2p orbital.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

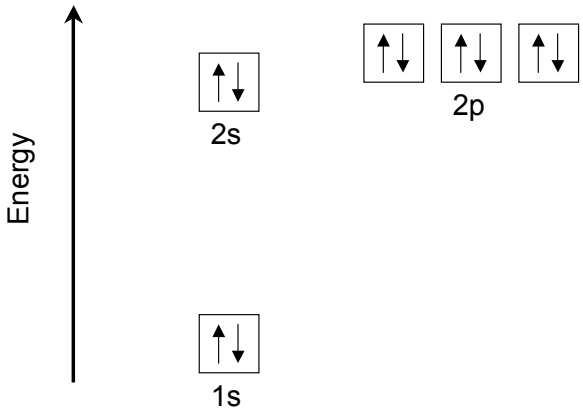
Oxygen (O): 8 electrons



The 8th electron has choice—it may either go into the 3s orbital to avoid pairing with another electron, or it may pair with a 2p electron which it doesn't like to do. The repulsive energy of pairing up is not as great as the higher energy of the 3s orbital, so this e⁻ goes into a 2p orbital.

Placement of Electrons in Atomic Orbitals
(remember e⁻'s go into lowest energy orbital available)

Neon (Ne): 10 electrons



The 10th electron could either pair with one of the other 2p e⁻'s or go into the 3s orbital. Because the 3s orbital is higher in energy than the cost of pairing up, this e⁻ occupies the last available spot in the 2p orbitals and completes the n=2 principal quantum number shell.

Electron Configuration

An atom's "electron configuration" is a shorthand way of describing which orbitals are occupied with electrons in the atoms.

Electron Configuration

The electron configuration is expressed by first writing the principal quantum number and letter of each occupied orbital. The number of electrons in the orbital is denoted by a superscript.

principal quantum number

Hydrogen: $1s^1$ number of e⁻'s in orbital

orbital occupied

Electron Configuration (con't.)

Helium—from the orbital energy diagram, we know that helium has two electrons in the 1s orbital:

- What is principal quantum number?
- Which orbitals do electrons occupy?
- How many electrons in each type of orbital?

principal quantum number

Helium: $1\,s^2$ number of e^-'s in orbital

orbital occupied

Electron Configuration (con't.)

Lithium—two electrons in the 1s orbital and one electron in the 2s orbital:

- Start with electron configuration of helium.
- What is principal quantum number of next electron?
- Which orbital does next electron occupy?
- How many electrons in this orbital?

Lithium: $1\,s^2\ 2\,s^1$

Electron Configuration (con't.)

Boron—two electrons in 1s orbital, two electrons in 2s orbital, one electron in 2p orbital:

- Start with electron configuration of beryllium.
- What is principal quantum number of next electron?
- Which orbital does next electron occupy?
- How many electrons in this orbital?

Boron: $1s^2\ 2s^2\ 2p^1$

Electron Configuration (con't.)

Neon—two electrons in 1s orbital, two electrons in 2s orbital, six electrons in 2p orbital:

- Start with electron configuration of beryllium.
- What is principal quantum number of next electron?
- Which orbital does next electron occupy?
- How many electrons in this orbital?

Neon: $1s^2\ 2s^2\ 2p^6$

Electron Configuration (con't.)

Sodium (Na)—next electron is in the 3s orbital:

- Start with electron configuration of neon—abbreviate neon electron configuration as [Ne] = $1s^2\ 2s^2\ 2p^6$.
- What is principal quantum number of next electron?
- Which orbital does next electron occupy?
- How many electrons in this orbital?

Sodium: [Ne] $3s^1$

Electron Configuration (con't.)

Sulfur (S)—four electrons in the 3p orbital:

- Start with electron configuration of magnesium.
- What is principal quantum number of next electron?
- Which orbital does next electron occupy?
- How many electrons in this orbital?

Sulfur: [Ne] $3s^2\ 3p^4$

Electron Configuration (con't.)

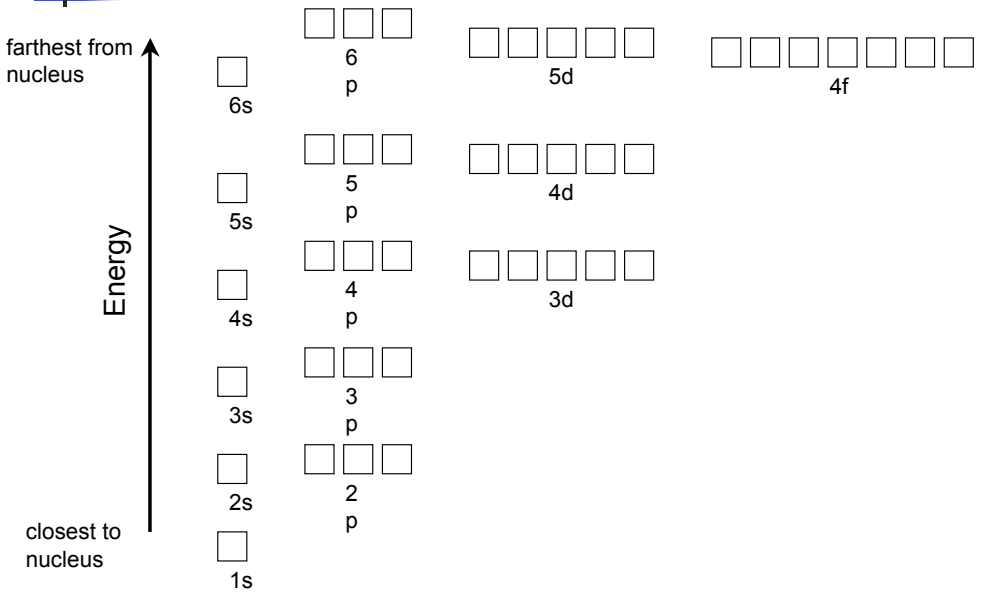
Iron (Fe):

- Start with electron configuration of argon (Ar): abbreviated [Ar] = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
- Where do next two electrons go?
- Where do next electrons go—4p or 3d? Why?

Orbital energy diagrams shows that 3d orbitals are higher in energy than 4s orbitals, but lower in energy than 4p orbitals.

Iron: [Ar] $4s^2$ 3 d ^{6}

Orbital Energy Diagram



Periodic Table and Electron Configuration