Orbitals

Unit: Electronic Structure

MA Curriculum Frameworks (2016): HS-PS1-1

Mastery Objective(s): (Students will be able to…)

- Explain the energy hierarchy of quantum levels, sub-levels, and orbitals.
- Explain how the hierarchy of quantum levels, sub-levels and orbitals corresponds with positions on the periodic table of the elements.

Success Criteria:

- Descriptions relate principal quantum number to period and sub-level to region of the periodic table.

Tier 2 Vocabulary: level, sub-level

Language Objectives:

- Explain the energy hierarchy of quantum levels, sub-levels and orbitals.

Notes:

orbital: a region in an atom (outside the nucleus) with a high probability of finding an electron.

These regions are called *orbitals* because these regions are what replaced the spherical orbits in the much simpler planetary model.

Note that orbitals are not physical objects with boundaries. They are simply the space that an electron moves around in because its energy and the external forces on it. When an electron approaches the "boundary" of its orbital, the forces pulling it back are strong enough to overcome the energy that the electron has, and it cannot get farther away.

The locations and geometric shapes of these orbitals are the solutions to the wave equation, a complex mathematical formula that would require mathematics far too advanced for a high school class. Instead, we will categorize orbitals using a hierarchy that is divided according to energy levels.

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Energy Level Hierarchy

Electrons have energy levels, which roughly correspond to the values of *n* in the Rutherford-Bohr model. Each of those levels has one or more kinds of sublevels. Each sublevel has one or more orbitals, and each of those orbitals can hold up to two electrons. It's easiest to think of the hierarchy as an outline:

1. energy level (1, 2, 3, ...)
    a. sub-level (s, p, d, f, ...)
        i. orbital
            a. individual electron

Energy Level

The main or principal level is a measure of total distance from the nucleus. The levels are numbered 1-7. The periodic table of the elements is arranged so that the Period (row number) that an element is in equals the energy level of the electron that has the most energy.

For example, helium is in period (row) #1. That means its highest energy level is 1, which means both of its electrons have to be in level 1.

Sulfur is in period (row) #3, which means it has electrons in levels 1, 2, and 3.

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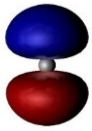
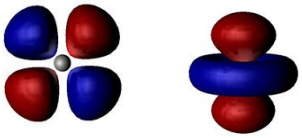
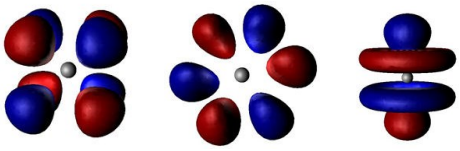
Sub-Levels & Orbitals

There are four types of sub-levels. Each type has a specific number of orbitals with specific shapes. Each of those orbitals can hold up to 2 electrons.

There are four kinds of sub-levels: **s, p, d,** and **f***. The shapes of their orbitals are:

type of sub-level	shape(s) of orbital(s)	total # of orbitals	total # of electrons
s		1	2
p		3	6
d		5	10
f		7	14

Notice that each sub-level has an odd number of orbitals.

* The letters come from words that described the characteristics of the atomic spectra. **s** stood for "sharp," **p** for "principal," **d** for "diffuse," and **f** for "fundamental."

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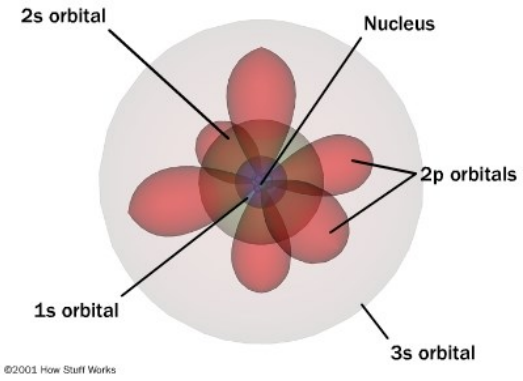
Arrangement of Levels and Sublevels

Each energy level in an atom has at least one of these kinds of sub-levels—each level contains an *s* sub-level, each level starting with level 2 contains *s* and p sub-levels, each level starting with level 3 contains s, p, and d sub-levels, *etc.*

Level	1	2	3	4	5	6	7
# of sub-levels	1	2	3	4	5	6	7
types of sub-levels	*s*	*s, p*	*s, p, d*	*s, p, d, f*	*s, p, d, f, (g)*	*s, p, d, f, (g), (h)*	*s, p, d, f, (g), (h), (i)*

Note that *g*, *h*, and *i* are in parentheses because no atom is large enough that it actually has any electrons in *g*, *h*, or *i* sublevels, but mathematically we know that those sub-levels will exist if we "discover" (create) a large enough atom.

Note also that these sub-levels overlap. For example, the levels and sublevels in a sodium (Na) atom might look like the following:



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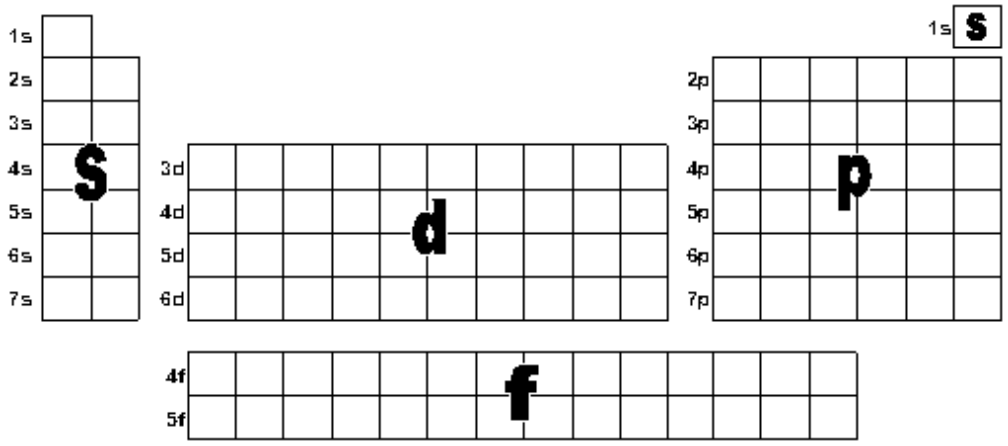
Sub-levels and the Periodic Table

Note that the sub-level of the electron that has the highest energy corresponds with the location of the element on the periodic table:



Notice, for example, that the "**s** section" of the periodic table is two columns wide. This is because each **s** sub-level has one orbital that can hold two electrons.

type of sub-level	# orbitals × 2 =	# electrons	# columns on P.T.
s	1	2	2
p	3	6	6
d	5	10	10
f	7	14	14

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