The Quantum Model of the Atom

After Rutherford and his colleagues determined the subatomic components of the nucleus, scientists began to look more closely where the electrons were located and why they did not collapse into the nucleus. Niels Bohr proposed that electrons existed at stable orbits about the nucleus. Electrons would fill the lowest energy orbits first, and each orbit (n) could hold a set number of electrons ($2n^2$). This theory is used as the basis for representing atoms using the Bohr-Rutherford Model.

However, Bohr's model was only the first step in the development of the quantum model of the atom. Over the course of the first half of the 20th century, the model was further refined to more precisely explain the position and behaviour of electrons in an atom.

A key to understanding the quantum model is that we now must think of electrons being located in a 3D region in space, rather than on a fixed 2D orbit.

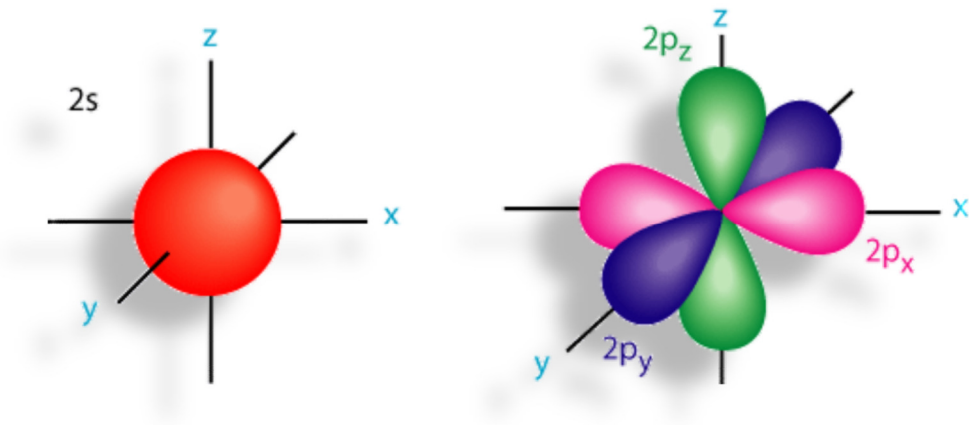
Key Features of the Quantum Model

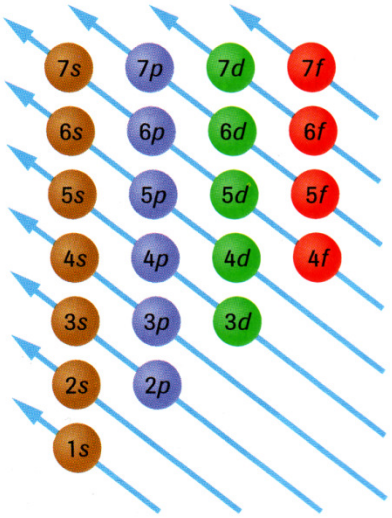
1. There are major energy levels (also called orbits or shells), similar to Bohr-Rutherford model. Major levels have an average energy level and distance from the nucleus. They are represented by "***n***" and can contain a maximum number of electrons (**$2n^2$**). (Level 1, 2, 3 etc.)

2. Energy levels have overlapping subshells that are divided into 4 different types (s, p, d and f), based on the maximum number of *orbitals* (and electrons) they can have. (note that lower energy levels do not have all 4 types of subshells)

3. *Orbitals* can hold 2 electrons each, in different orientations and shapes, and are the regions of space electrons are likely moving in (see the three p orbital below).

- **s** can hold 2 electrons (one spherical orbital)
- **p** can hold 6 electrons (2 in each of 3 orbital orientations)
- **d** can hold 10 electrons (2 in each of 5 orbitals)
- **f** can hold 14 electrons (2 in each of 7 orbitals)



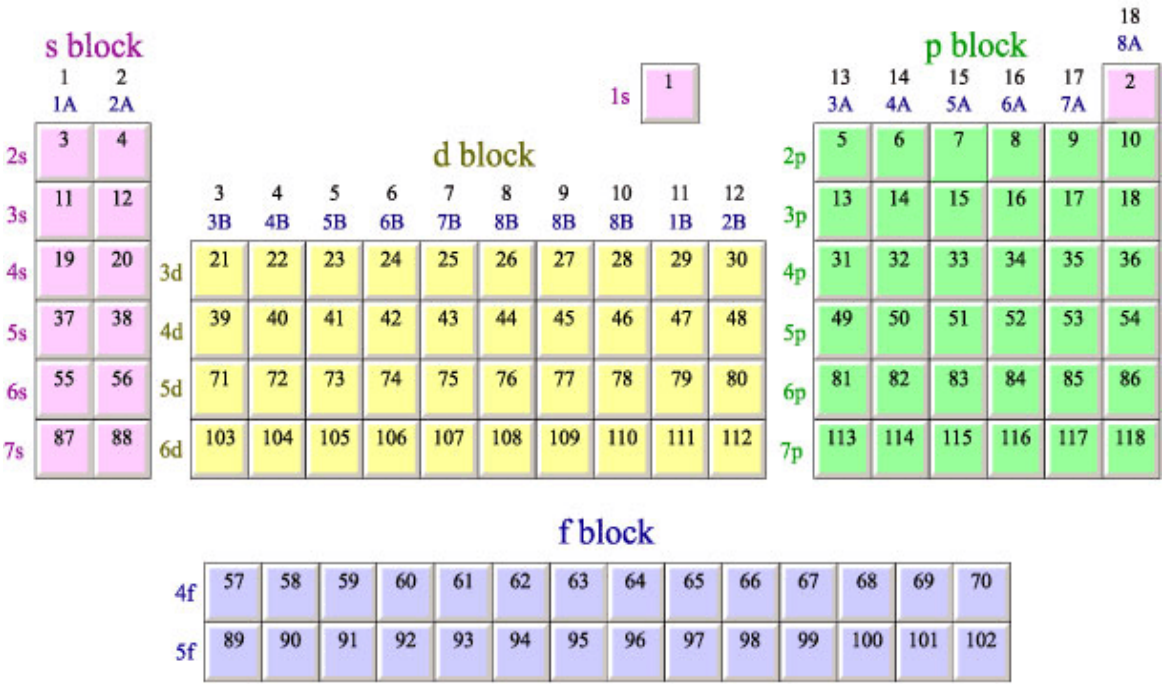


4. As in the Bohr model, shells and sub-shells are filled according to the Aufbau principle (lowest energy ones filled first).

5. Shells and orbitals are regions of space around the nucleus where electrons are most likely to be found, also called electron clouds.

6. Each subshell type (s,p,d,f) has a unique shape. It turns out that only s is spherical, so the actual quantum model is considerably more difficult to draw. Also, as the levels get further from the nucleus, some of the levels actually overlap.

For example, the d sub-level is a lobed-shaped structure that originates in level 3, but the electrons spend most of their time near the tips of the lobes which is actually further from the nucleus than the s sub-level in level 4. Thus, it takes less energy to place electrons in 4 s than 3 d. So 4s is filled prior to 3d. This pattern of overlap repeats more and more in higher levels so a system has been devised to predict the order of sub-level filling based on moving from lowest to highest amount of energy needed. Fortunately, the periodic table is designed to help determine which orbitals are occupied in atoms.



Add your own notes on Energy level diagrams and electron configuration notation as we discuss it in class.