Modern Atomic Theory

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CONCEPT 1 Modern Atomic Theory

Lesson Objectives

- Define energy levels.
- Describe the electron cloud and orbitals.

Vocabulary

- electron cloud
- energy level
- orbital

Introduction

Rutherford's model of the atom was better than earlier models. But it wasn't the last word. Danish physicist Niels Bohr created a more accurate and useful model. Bohr's model was an important step in the development of modern atomic theory. The video at the URL below is a good introduction to modern atomic theory. It also reviews important concepts from the previous two lessons, "Inside the Atom" and "History of the Atom."

http://www.khanacademy.org/video/introduction-to-the-atom?playlist=Chemistry

Bohr's Model of the Atom

Bohr's research focused on electrons. In 1913, he discovered evidence that the orbits of electrons are located at fixed distances from the nucleus. Remember, Rutherford thought that electrons orbit the nucleus at random. **Figure** 1.1 shows Bohr's model of the atom.

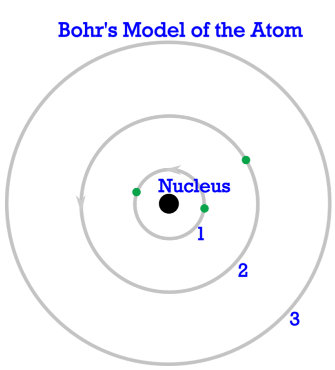

FIGURE 1.1
In Bohr's atomic model, electrons orbit at fixed distances from the nucleus. These distances are called energy levels.

Energy Levels

Basic to Bohr's model is the idea of energy levels. **Energy levels** are areas located at fixed distances from the nucleus of the atom. They are the only places where electrons can be found. Energy levels are a little like rungs on a ladder. You can stand on one rung or another but not between the rungs. The same goes for electrons. They can occupy one energy level or another but not the space between energy levels.

The model of an atom in **Figure** 1.2 has six energy levels. The level with the least energy is the one closest to the nucleus. As you go farther from the nucleus, the levels have more and more energy. Electrons can jump from one energy level to another. If an atom absorbs energy, some of its electrons can jump to a higher energy level. If electrons jump to a lower energy level, the atom emits, or gives off, energy. You can see an animation at this happening at the URL below.

http://cas.sdss.org/dr6/en/proj/advanced/spectraltypes/energylevels.asp

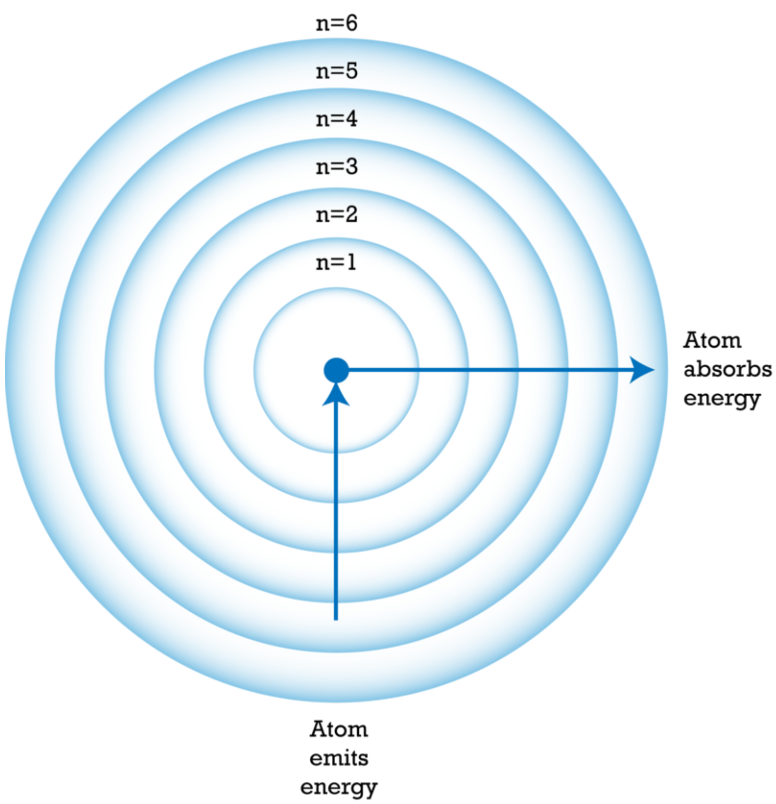

FIGURE 1.2

This model of an atom contains six energy levels (n = 1 to 6). Atoms absorb or emit energy when some of their electrons jump to a different energy level.

Energy Levels in Action

Bohr's idea of energy levels is still useful today. It helps explain how matter behaves. For example, when chemicals in fireworks explode, their atoms absorb energy. Some of their electrons jump to a higher energy level. When the electrons move back to their original energy level, they give off the energy as light. Different chemicals have different arrangements of electrons, so they give off light of different colors. This explains the blue- and purple-colored fireworks in **Figure** 1.3.

FIGURE 1.3
Atoms in fireworks give off light when their electrons jump back to a lower energy level.

Electron Cloud and Orbitals

In the 1920s, physicists discovered that electrons do not travel in fixed paths. In fact, they found that electrons only have a certain chance of being in any particular place. They could only describe where electrons are with mathematical formulas. That's because electrons have wave-like properties as well as properties of particles of matter. It is the "wave nature" of electrons that lets them exist only at certain distances from the nucleus. The negative electrons are attracted to the positive nucleus. However, because the electrons behave like waves, they bend around the nucleus instead of falling toward it. Electrons exist only where the wave is stable. These are the orbitals. They do not exist where the wave is not stable. These are the places between orbitals.

Electron Cloud Model

Today, these ideas about electrons are represented by the electron cloud model. The **electron cloud** is an area around the nucleus where electrons are likely to be. **Figure** 1.4 shows an electron cloud model for a helium atom.

Orbitals

Some regions of the electron cloud are denser than others. The denser regions are areas where electrons are most likely to be. These regions are called **orbitals**. Each orbital has a maximum of just two electrons. Different energy levels in the cloud have different numbers of orbitals. Therefore, different energy levels have different maximum numbers of electrons. **Table** 1.1 lists the number of orbitals and electrons for the first four energy levels. Energy

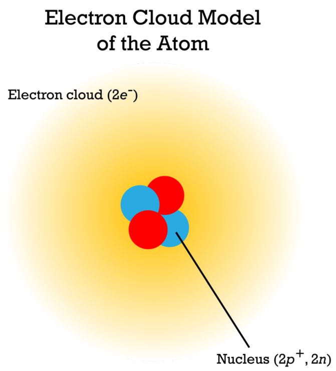

FIGURE 1.4
This sketch represents the electron cloud model for helium. What does the electron cloud represent?

levels farther from the nucleus have more orbitals. Therefore, these levels can hold more electrons.

TABLE 1.1: **First Four Energy Levels and Their Orbitals**

Energy Level	Number of Orbitals	Max. No. of Electrons (@ 2 per orbital)
1	1	2
2	4	8
3	9	18
4	16	32

Figure 1.5 shows the arrangement of electrons in an atom of magnesium as an example. The most stable arrangement of electrons occurs when electrons fill the orbitals at the lowest energy levels first before more are added at higher levels. You can learn more about orbitals and their electrons at the URL below: http://www.khanacademy.org/video/orbitals?playlist=Chemistry.

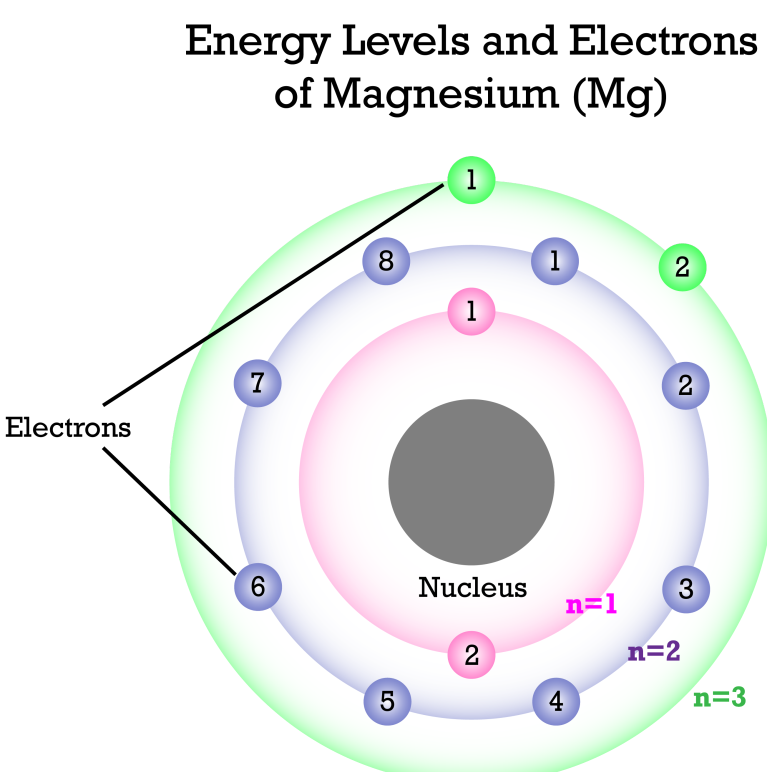

FIGURE 1.5
This model represents an atom of the element magnesium (Mg). How many electrons does the atom have at each energy level? What is the maximum number it could have at each level?

Lesson Review Questions

Recall

1. What are energy levels?
2. Which energy level has the smallest amount of energy?
3. Define orbitals.
4. How many electrons can be found in an orbital?

Apply Concepts

5. A change in energy caused an electron in an atom to jump from energy level 2 to energy level 3. Did the atom gain or lose energy? Explain.
6. Create a sketch to model the concept of the electron cloud.

Think Critically

7. Explain how orbitals are related to energy levels.

Points to Consider

In this chapter, you learned that atoms of each element have a unique number of protons. This is one way that each element differs from all other elements.

- How could the number of protons be used to organize elements?
- If one element has more protons than another element, how do their numbers of electrons compare?

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References

1. Joy Sheng. CK-12 Foundation. CC BY-NC 3.0
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