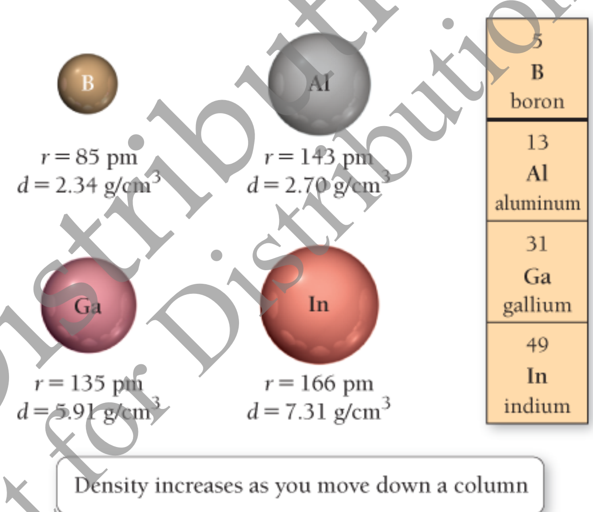
3.1: Aluminum: Low-Density Atoms Result in Low-Density Metal

Look out the window of almost any airplane and you will see the large sheets of aluminum that compose the aircraft's wing. In fact, the majority of the plane is most likely made out of aluminum. Aluminum has several properties that make it suitable for airplane construction, but among the most important is its low density. Aluminum has a density of only 2.70 g/cm^3. For comparison, iron's density is 7.86 g/cm^3, and platinum's density is 21.4 g/cm^3. Why is the density of aluminum metal so low?

The density of aluminum metal is low because the density of an aluminum atom is low. Few metal atoms have a lower mass-to-volume ratio than aluminum, and those that do can't be used in airplanes for other reasons (such as their high chemical reactivity). Although the *arrangements* of atoms in a solid must also be considered when evaluating the density of the solid, the mass-to-volume ratio of the composite atoms is a very important factor. For this reason, the densities of the elements generally follow a fairly well-defined trend: *The density of elements tends to increase as we move down a column in the periodic table*. For example, consider the densities of several elements in the column that includes aluminum in the periodic table:



As we move down the column in the periodic table, the density of the elements increases even though the radius generally increases as well (with the exception of Ga whose radius decreases a bit). Why? *Because the mass of each successive atom increases even more than its volume does*. As we move down a column in the periodic table, the additional protons and neutrons add more mass to the atoms. This increase in mass is greater than the increase in volume, resulting in a higher denstity.

The densities of elements and the radii of their atoms are examples of *periodic properties*. A **periodic property** is one that is generally predictable based on an element's position within the periodic table. In this chapter, we examine several periodic properties of elements, including atomic radius, ionization energy, and electron affinity. As we do, we will see that these properties—as well as the overall arrangement of the periodic table—are explained by quantum-mechanical theory, which we first examined in Chapter 2. *Quantum-mechanical theory explains the electronic structure of atoms—this in turn determines the properties of those atoms*.

Notice again that *structure determines properties*. The arrangement of elements in the periodic table—originally based on similarities in the properties of the elements—reflects how electrons fill quantum-mechanical orbitals. Understanding the structure of atoms as explained by quantum mechanics allows us to predict the properties of

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elements from their position on the periodic table. If we need a metal with a high density, for example, we look toward the bottom of the periodic table. Platinum (as we saw previously) has a density of 21.4 g/cm^3. It is among the densest metals and is found near the bottom of the periodic table. If we need a metal with a low density, we look toward the top of the periodic table. Aluminum is among the least dense metals and is found near the top of the periodic table.

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