2.5: Some Characteristics of Different Groups

Learning Objectives

- Describe how some characteristics of elements relate to their positions on the periodic table.

The periodic table is useful for understanding atomic properties that show **periodic trends**. Periodic trends are specific patterns that are present in the periodic table that illustrate different aspects of a certain element, including its size and its electronic properties. Major periodic trends include atomic radius, melting point, among many other properties as we will discuss. Periodic trends, arising from the arrangement of the periodic table, provide chemists with an invaluable tool to quickly predict an element's properties. These trends exist because of the similar atomic structure of the elements within their respective group families or periods, and because of the periodic nature of the elements.

One important atomic property is the **atomic radius**, which is a measure of the atomic size, usually the distance from the nucleus to the out electron shell. However, since this boundary is not well-defined, there are multiple definitions of atomic radius. Irrespective of the definition used, a clear periodic trend can be observed when atomic radius is plotted vs. atomic number (Figure $2.5.1$). The radii generally decrease along each row of the table and increase down each group. The radius increases sharply between the noble gas at the end of each period and the alkali metal at the beginning of the next period. The largest atoms are found in the lower left corner of the periodic table and the smallest are found in the upper right corner

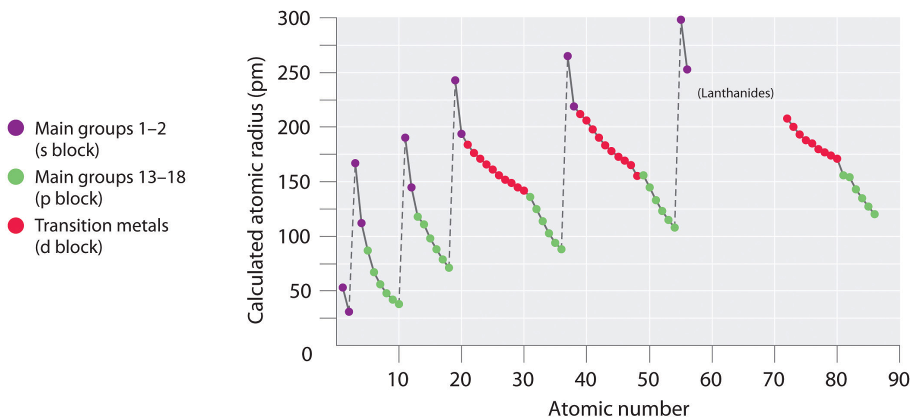

Figure $2.5.1$: A Plot of Periodic Variation of Atomic Radius with Atomic Number for the First Six Rows of the Periodic Table.

The melting point is a metric of the energy required to transform the solid phase of a substance into a liquid. Generally, the stronger the bond between the atoms of an element, the more energy required to break that bond. The melting points exhibit comparable, albeit more complex, periodic trends as observed in the atomic radii (Figure $2.5.2$). Key feature of these trends are:

- Metals generally possess a *high melting point*.
- Most non-metals possess *low melting points*.
- The non-metal carbon possesses *the highest melting point of all the elements*. The semi-metal boron also possesses a high melting point.

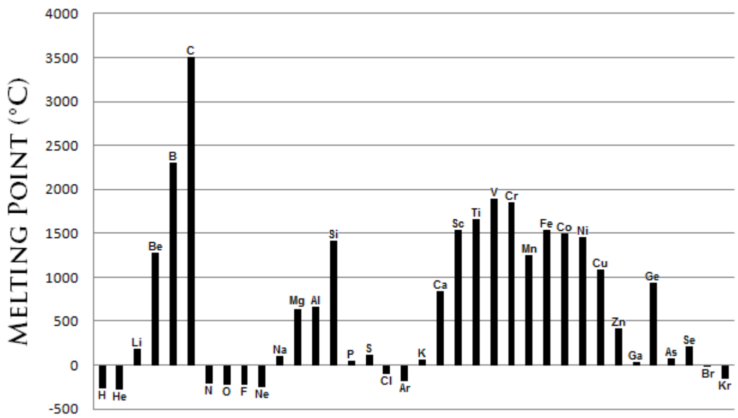

Figure 2.5.2: A plot of melting point vs. atomic number show a periodic trend.

The trends of the atomic radii and melting points (and other chemical and physical properties of the elements) can be explained by the electron shell theory of the atom discussed in the following sections.

Element Characteristics By Group

The periodic table is arranged so that elements with similar chemical behaviors are in the same group. Chemists often make general statements about the properties of the elements in a group using descriptive names with historical origins. For example, the elements of Group 1 are known as the alkali metals, Group 2 are the alkaline earth metals, Group 17 are the halogens, and Group 18 are the noble gases.

- **Group 1: The Alkali Metals –** lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr) are soft, shiny, and highly reactive metals. The compounds of the alkali metals are common in nature and daily life. One example is table salt (sodium chloride); lithium compounds are used in greases, in batteries, and as drugs to treat patients who exhibit manic-depressive, or bipolar, behavior. Although lithium, rubidium, and cesium are relatively rare in nature, and francium is so unstable and highly radioactive that it exists in only trace amounts, sodium and potassium are the seventh and eighth most abundant elements in Earth's crust, respectively. *Hydrogen is unique in that it is generally placed in Group 1, but it is not a metal.*
- **Group 2: The Alkaline Earth Metals –** beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra) are shiny, slivery-white, somewhat reactive metals. Beryllium, strontium, and barium are rare, and radium is unstable and highly radioactive. In contrast, calcium and magnesium are the fifth and sixth most abundant elements on Earth, respectively; they are found in huge deposits of limestone and other minerals.
- **Group 17: The Halogens –** fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At) are nonmetals. The name halogen is derived from the Greek words for "salt forming," which reflects that all the halogens react readily with metals to form compounds, such as sodium chloride and calcium chloride (used in some areas as road salt).
- **Group 18: The Noble Gases –** helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn) are gases at room temperature and pressure. Because the noble gases are composed of only single atoms, they are called monatomic. Because of their lack of reactivity, for many years they were called **inert gases** or rare gases. However, the first chemical compounds containing the noble gases were prepared in 1962. Although the noble gases are relatively minor constituents of the atmosphere, natural gas contains substantial amounts of helium. Because of its low reactivity, argon is often used as an unreactive (inert) atmosphere for welding and in light bulbs. The red light emitted by neon in a gas discharge tube is used in neon lights.

To Your Health: Radon

Radon is an invisible, odorless noble gas that is slowly released from the ground, particularly from rocks and soils whose uranium content is high. Because it is a noble gas, radon is not chemically reactive. Unfortunately, it is radioactive, and increased exposure to it has been correlated with an increased lung cancer risk.

Because radon comes from the ground, we cannot avoid it entirely. Moreover, because it is denser than air, radon tends to accumulate in basements, which if improperly ventilated can be hazardous to a building's inhabitants. Fortunately, specialized ventilation minimizes the amount of radon that might collect. Special fan-and-vent systems are available that draw air from below the basement floor, before it can enter the living space, and vent it above the roof of a house.

After smoking, radon is thought to be the second-biggest *preventable* cause of lung cancer in the United States. The American Cancer Society estimates that 10% of all lung cancers are related to radon exposure. There is uncertainty regarding what levels of exposure cause cancer, as well as what the exact causal agent might be (either radon or one of its breakdown products, many of which are also radioactive and, unlike radon, not gases). The US Environmental Protection Agency recommends testing every floor below the third floor for radon levels to guard against long-term health effects.

Example 2.5.1: Groups

Provide the family/group names and period numbers (horizontal values) of each element.

a. Li
b. Ar
c. Ra

Solution:

a. Lithium is an alkali metal. It is located in period two.
b. Argon is a noble gas. It is located in period three.
c. Radium is an alkaline metal. It is located in period seven.

Example 2.5.2: Classification of Elements

Provide elemental names for the following combinations:

a. The alkali metal in period three.
b. The halogen in period two
c. A metalloid in period four
d. A transition metal in period three

Solution:

a. Sodium
b. Fluorine
c. Germanium or Arsenic
d. There are no transition metals in period three (gotcha!)

Key Takeaways

- The chemical elements are arranged in a chart called the periodic table.
- Some characteristics of the elements are related to their position on the periodic table.
- The number of valence electrons of an element can be determined by the group (vertical column) number in the Periodic Table. Elements with the same number of valence electrons have similar chemical properties.