Pearson

3.8: Electron Affinities and Metallic Character

Electron affinity and metallic character also exhibit periodic trends. Electron affinity is a measure of how easily an atom accepts an additional electron and is crucial to chemical bonding because bonding involves the transfer or sharing of electrons. Metallic character is important because of the high proportion of metals in the periodic table and the large role they play in our lives. Of the 118 known elements, 92 are metals. We examine each of these periodic properties individually in this section.

Electron Affinity

The **electron affinity (EA)** of an atom or ion is the energy change associated with the gaining of an electron by the atom in the gaseous state. Electron affinity is usually—though not always—negative because an atom or ion usually releases energy when it gains an electron. (The process is exothermic, which, as discussed in Chapter E, gives off heat and therefore carries a negative sign.) In other words, the coulombic attraction between the nucleus of an atom and the incoming electron usually results in the release of energy as the electron is gained. For example, we can represent the electron affinity of chlorine with the equation:

$$\mathrm{Cl}(g) + 1\ \mathrm{e}^- \rightarrow \mathrm{Cl}^-(g) \qquad \mathrm{EA} = -349\ \mathrm{kJ/mol}$$

Figure 3.20 displays the electron affinities for a number of main-group elements. As we can see from this figure, the trends in electron affinity are not as regular as trends in other properties we have examined. For instance, we might expect electron affinities to become relatively more positive (so that the addition of an electron is less exothermic) as we move down a column because the electron is entering orbitals with successively higher principal quantum numbers and will therefore be farther from the nucleus. This trend applies to the group 1A metals but does not hold for the other columns in the periodic table.

Figure 3.20 Electron Affinities of Selected Main-Group Elements

Electron Affinities (kJ/mol)

1A	2A	3A	4A	5A	6A	7A	8A
H −73							He >0
Li −60	Be >0	B −27	C −122	N >0	O −141	F −328	Ne >0
Na −53	Mg >0	Al −43	Si −134	P −72	S −200	Cl −349	Ar >0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr >0
Rb −47	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe >0

A more regular trend in electron affinity, however, occurs as we move to the right across a row. Based on the periodic properties we have learned so far, would you expect more energy to be released when an electron is gained by Na or Cl? We know that Na has an outer electron configuration of $3s^1$ and Cl has an outer electron configuration of $3s^2\ 3p^5$. Because adding an electron to chlorine gives it a noble gas configuration and adding an electron to sodium does not, and because the outermost electrons in chlorine experience a higher Z_{eff} than the outermost electrons in sodium, we would expect chlorine to have a more negative electron affinity—the process should be more exothermic for chlorine. This is in fact the case. For main-group elements, electron affinity generally becomes more negative (more exothermic) as we move to the right across a row in the periodic table. The halogens (group 7A) therefore have the most negative electron affinities. But exceptions do occur. For example, notice that nitrogen and the other group 5A elements do not follow the general trend. These elements have $ns^2\,np^3$ outer electron configurations. When an electron is added to this configuration, it must pair with another electron in an already occupied p orbital. The repulsion between two electrons occupying the same orbital causes the electron affinity to be more positive than that for elements in the previous column.

Summarizing Electron Affinity for Main-Group Elements

- Most groups (columns) of the periodic table do not exhibit any definite trend in electron affinity. Among the group 1A metals, however, electron affinity becomes more positive as we move down the column (adding an electron becomes less exothermic).
- Electron affinity generally becomes more negative (adding an electron becomes more exothermic) as we move to the right across a period (row) in the periodic table.

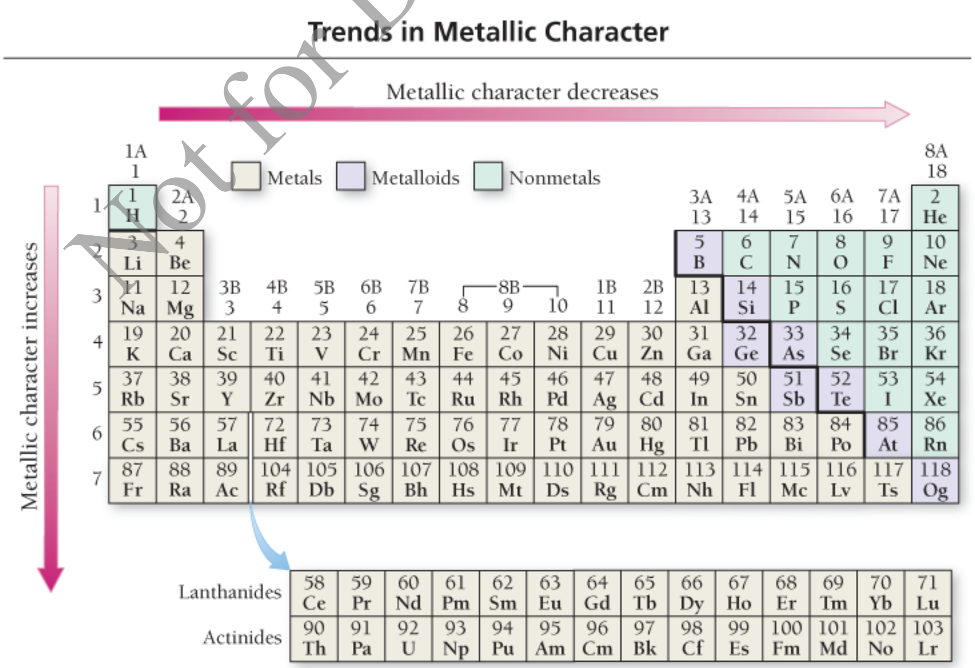
Metallic Character

As we discussed in Section 3.5, metals are good conductors of heat and electricity; they can be pounded into flat sheets (malleability); they can be drawn into wires (ductility); they are often shiny; and they tend to lose electrons in chemical reactions. Nonmetals, in contrast, have more varied physical properties; some are solids at room temperature, others are gases, but in general nonmetals are typically poor conductors of heat and electricity, and they all tend to gain electrons in chemical reactions. As we move to the right across a row in the periodic table, ionization energy increases and electron affinity becomes more negative; therefore, elements on the left side of the periodic table are more likely to lose electrons than elements on the right side of the periodic table (which are more likely to gain them). The other properties associated with metals follow the same general trend (even though we do not quantify them here). Consequently, as shown in Figure 3.21:

> As we move to the right across a row (or period) in the periodic table, metallic character decreases.

Figure 3.21 Trends in Metallic Character I

Metallic character decreases as we move to the right across a period and increases as we move down a column in the periodic table.



As we move down a column in the periodic table, first ionization energy decreases, making electrons more likely to be lost in chemical reactions. Consequently:

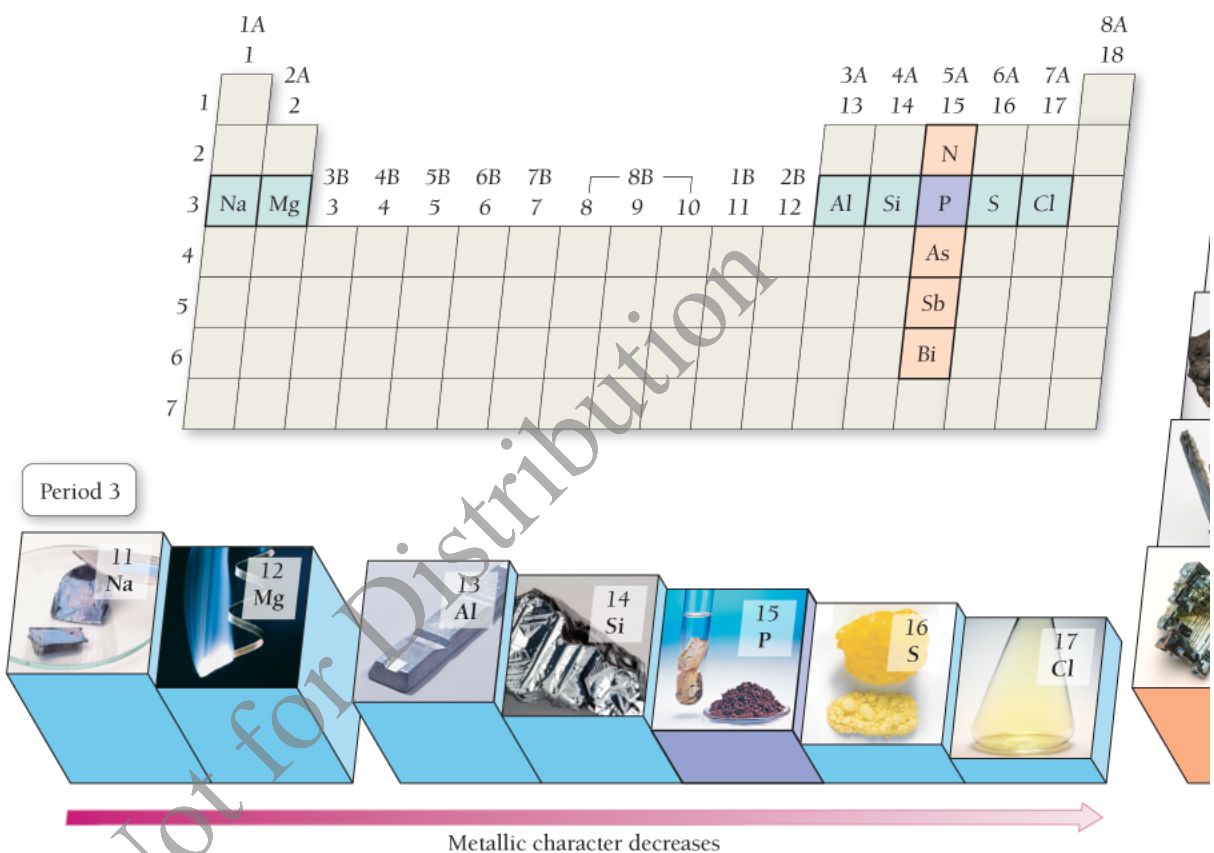
As we move down a column (or family) in the periodic table, metallic character increases.

These trends explain the overall distribution of metals and nonmetals in the periodic table first discussed in Section 3.5. Metals are found on the left side and toward the center and nonmetals on the upper right side. The change in chemical behavior from metallic to nonmetallic can be seen most clearly as we proceed to the right across period 3, or down along group 5A as shown in Figure 3.22.

Figure 3.22 Trends in Metallic Character II

As we move down group 5A in the periodic table, metallic character increases. As we move across period 3, metallic character decreases.

Trends in Metallic Character



Example 3.10 Metallic Character

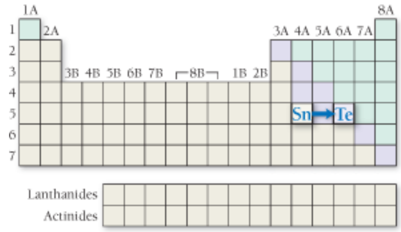
On the basis of periodic trends, choose the more metallic element from each pair (if possible).

a. Sn or Te
b. P or Sb
c. Ge or In
d. S or Br

SOLUTION

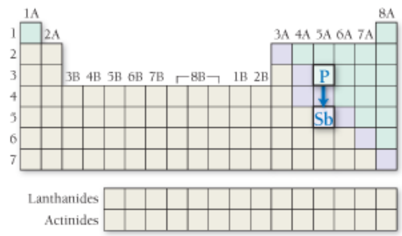
a. Sn or Te

Sn is more metallic than Te because, as you trace the path between Sn and Te on the periodic table, you move to the right within the same period. Metallic character decreases as you move to the right.



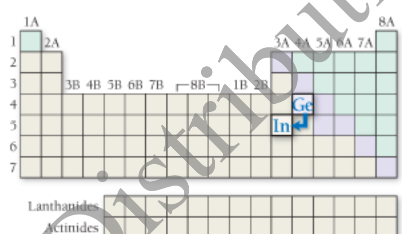
b. P or Sb

Sb is more metallic than P because, as you trace the path between P and Sb on the periodic table, you move down a column. Metallic character increases as you move down a column.



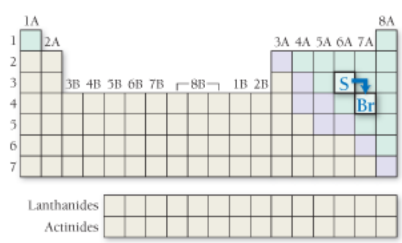
c. Ge or In

In is more metallic than Ge because, as you trace the path between Ge and In on the periodic table, you move down a column (metallic character increases) and then to the left across a period (metallic character increases). These effects add together for an overall increase.



d. S or Br

Based on periodic trends alone, we cannot tell which is more metallic because as you trace the path between S and Br, you go to the right across a period (metallic character decreases) and then down a column (metallic character increases). These effects tend to counter each other, and it is not obvious which will predominate.



FOR PRACTICE 3.10 On the basis of periodic trends, choose the more metallic element from each pair (if possible).

a. Ge or Sn
b. Ga or Sn
c. P or Bi
d. B or N

FOR MORE PRACTICE 3.10 Arrange the following elements in order of increasing metallic character: Si, Cl, Na, Rb.

Conceptual Connection 3.8 Periodic Trends

Interactive