Ionization Energy

As they do for the main-group elements, ionization energies of the *d*-block and *f*-block elements generally increase across the periods. In contrast to the decrease down the main groups, however, the first ionization energies of the *d*-block elements generally increase down each group. This is because the electrons available for ionization in the outer *s* sublevels are less shielded from the increasing nuclear charge by electrons in the incomplete $(n - 1)d$ sublevels.

Ion Formation and Ionic Radii

Among all atoms of the *d*-block and *f*-block elements, electrons in the highest occupied sublevel are always removed first. For the *d*-block elements, this means that although newly added electrons occupy the *d* sublevels, the first electrons to be removed are those in the outermost *s* sublevels. For example, iron, Fe, has the electron configuration $[Ar]3d^6 4s^2$. First, it loses two 4*s* electrons to form Fe^{2+} ($[Ar]3d^6$). Fe^{2+} can then lose a 3*d* electron to form Fe^{3+} ($[Ar]3d^5$).

Most *d*-block elements commonly form 2+ ions in compounds. Some, such as iron and chromium, also commonly form 3+ ions. The Group 3 elements form only ions with a 3+ charge. Copper forms 1+ and 2+ ions, and silver usually forms only 1+ ions. As expected, the cations have smaller radii than the atoms do. Comparing 2+ ions across the periods shows a decrease in size that parallels the decrease in atomic radii.

Electronegativity

The *d*-block elements all have electronegativities between 1.1 and 2.54. Only the active metals of Groups 1 and 2 have lower electronegativities. The *d*-block elements also follow the general trend for electronegativity values to increase as radii decrease, and vice versa. The *f*-block elements all have similar electronegativities, which range from 1.1 to 1.5.

SECTION REVIEW

1. State the general period and group trends among main-group elements with respect to each of the following properties:
   - **a.** atomic radii
   - **b.** first ionization energy
   - **c.** electron affinity
   - **d.** ionic radii
   - **e.** electronegativity
2. **a.** In general, how do the periodic properties of the *d*-block elements compare with those of the main-group elements?
   b. Explain the comparisons made in (a).
3. For each main-group element, what is the relationship between its group number and the number of valence electrons that the group members have?

Critical Thinking

4. **RELATING IDEAS** Graph the general trends (left to right and top to bottom) in the second ionization energy (IE_2) of an element as a function of its atomic number, over the range Z = 1–20. Label the minima and maxima on the graph with the appropriate element symbol.