The Periodic Law

Mendeleev summarized his discoveries in the **periodic law**: The properties of chemical elements are not arbitrary, but vary with the atomic weight in a systematic way.

After most of the elements had been discovered and their atomic weights carefully determined, several discrepancies persisted. For example, the order of increasing atomic weight within Mendeleev's Group VIII (Figure 7-1) was found to be Fe, Co, Ni, Cu in the fourth period (row 4), Ru, Rh, Pd, Ag in the fifth (row 6), and Os, Ir, Pt, Au in the sixth (row 10). Yet Ni resembles Pd and Pt more than Co does. Again, Te has a higher atomic weight than I, but I clearly belongs with Br and Cl, and Te resembles Se and S in chemical properties. When the noble gases were discovered, it was revealed that Ar had a higher atomic weight than K, whereas all the other noble gases had lower atomic weights than the adjacent alkali metals. In these three instances, increasing atomic weight clearly is *not* acceptable as a means of placing elements in the periodic table. Therefore, the elements were assigned atomic numbers from 1 to 92 (now 105). (The atomic numbers of the elements *approximately* increase with their atomic weights.) When the elements are arranged according to increasing atomic number, chemically similar elements lie in vertical columns (families or groups) of the periodic table.

In 1912, Henry G. J. Moseley (1887–1915) observed that the frequencies of x rays emitted from elements could be correlated better with atomic numbers than with atomic weights. The relationship between an element's atomic number and the frequency (or energy) of x rays emitted from the element is a consequence of atomic structure. As we shall see in Chapter 8, the electrons in an atom are arranged in *energy levels*. When an element is bombarded by a powerful beam of electrons, electrons from the innermost levels or shells (closest to the nucleus) can be ejected from the atoms. When outer electrons drop into these shells to fill the vacancies, energy is emitted as x radiation. The x-ray spectrum of an element (the collection of frequencies of x rays emitted) contains information about the electronic energy levels of the atom. The important point for our present purpose is that the energy of a level varies with the charge on the nucleus of the atom. The greater the nuclear charge, the more tightly the innermost electrons are bound. More energy is required to knock off one of these electrons; consequently, there is more energy emitted when an electron falls back into a vacancy in the shells. Moseley discovered that the frequency of x rays emitted (designated by the Greek letter ν, nu) varies with atomic number, Z, according to

$$\nu = c(Z - b)^2$$

in which c and b are characteristic of a given x-ray line and are the same for all elements.

In April 1914, Moseley published the results of his work on 39 elements from $_{13}$Al to $_{79}$Au. (Recall that the atomic number is indicated by a sub-