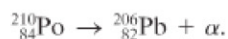## 30–10 Decay Series

It is often the case that one radioactive isotope decays to another isotope that is also radioactive. Sometimes this daughter decays to yet a third isotope which also is radioactive. Such successive decays are said to form a **decay series**. An important example is illustrated in Fig. 30–11. As can be seen, $^{238}_{92}U$ decays by α emission to $^{234}_{90}Th$, which in turn decays by β decay to $^{234}_{91}Pa$. The series continues as shown, with several possible branches near the bottom, ending at the stable lead isotope, $^{206}_{82}Pb$. The two last decays can be

$$^{206}_{81}Tl \rightarrow\ ^{206}_{82}Pb + e^- + \bar{\nu},$$

or

$$^{210}_{84}Po \rightarrow\ ^{206}_{82}Pb + \alpha.$$

Other radioactive series also exist.

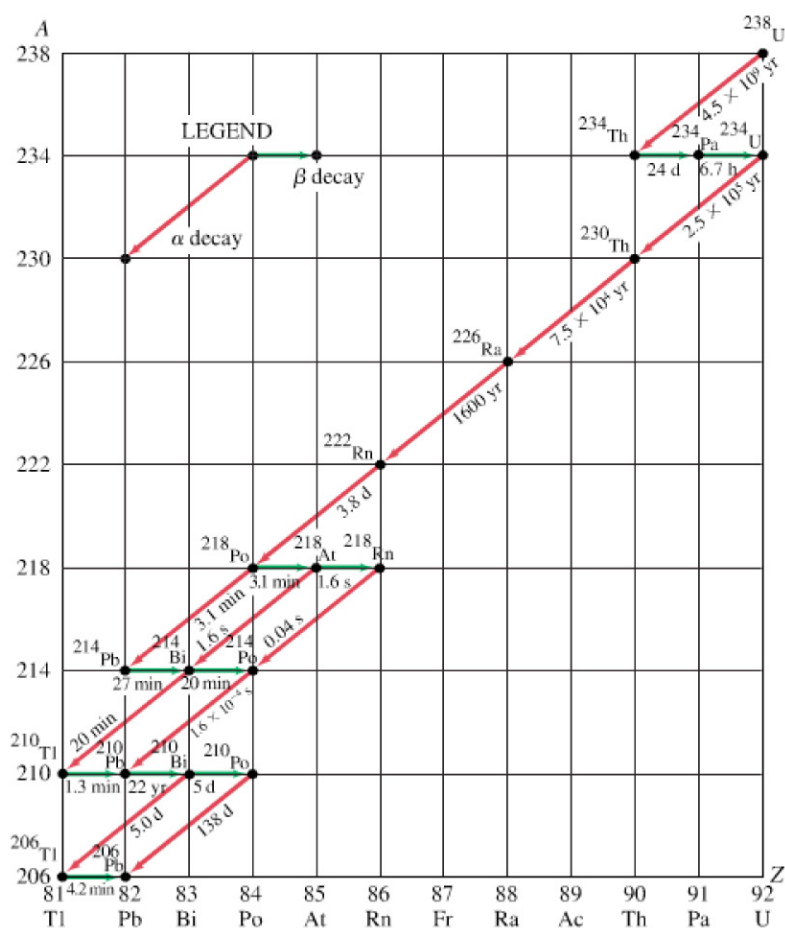**FIGURE 30–11** Decay series beginning with $^{238}_{92}U$. Nuclei in the series are specified by a dot representing A and Z values. Half-lives are given in seconds (s), minutes (min), hours (h), days (d), or years (yr). Note that a horizontal arrow represents β decay (A does not change), whereas a diagonal line represents α decay (A changes by 4, Z changes by 2).

Because of such decay series, certain radioactive elements are found in nature that otherwise would not be. For when the solar system acquired its present form about 5 billion years ago, it is believed that nearly all nuclides were formed (by the fusion process, Sections 31–3 and 33–2). Many isotopes with short half-lives decayed quickly and no longer are detected in nature today. But long-lived isotopes, such as $^{238}_{92}U$ with a half-life of 4.5×10^9 yr, still do exist in nature today. Indeed, about half of the original $^{238}_{92}U$ still remains (assuming that the origin of the solar system was about 5×10^9 yr ago). We might expect, however, that radium ($^{226}_{88}Ra$), with a half-life of 1600 yr, would long since have disappeared from the Earth. Indeed, the original $^{226}_{88}Ra$ nuclei must by now have all decayed. However, because $^{238}_{92}U$ decays (in several steps) to $^{226}_{88}Ra$, the supply