What, you may wonder, is the difference between a γ ray and an X-ray? They both are electromagnetic radiation (photons) and, though γ rays usually have higher energy than X-rays, their range of energies overlap to some extent. The difference is not intrinsic. We use the term X-ray if the photon is produced by an electron–atom interaction, and γ ray if the photon is produced in a nuclear process.

TABLE 30–2 The Three Types of Radioactive Decay

α decay:
${}^{A}_{Z}\text{N} \rightarrow {}^{A-4}_{Z-2}\text{N}' + {}^{4}_{2}\text{He}$
β decay:
${}^{A}_{Z}\text{N} \rightarrow {}^{A}_{Z+1}\text{N}' + e^{-} + \bar{\nu}$
${}^{A}_{Z}\text{N} \rightarrow {}^{A}_{Z-1}\text{N}' + e^{+} + \nu$
${}^{A}_{Z}\text{N} + \text{e}^{-} \rightarrow {}^{A}_{Z-1}\text{N}' + \nu$ [EC]†
γ decay:
${}^{A}_{Z}\text{N}^{*} \rightarrow {}^{A}_{Z}\text{N} + \gamma$

† Electron capture.
* Indicates the excited state of a nucleus.

30–7 Conservation of Nucleon Number and Other Conservation Laws

In all three types of radioactive decay, the classical conservation laws hold. Energy, linear momentum, angular momentum, and electric charge are all conserved. These quantities are the same before the decay as after. But a new conservation law is also revealed, the **law of conservation of nucleon number**. According to this law, the total number of nucleons (A) remains constant in any process, although one type can change into the other type (protons into neutrons or vice versa). This law holds in all three types of decay. Table 30–2 gives a summary of α, β, and γ decay.

30–8 Half-Life and Rate of Decay

A macroscopic sample of any radioactive isotope consists of a vast number of radioactive nuclei. These nuclei do not all decay at one time. Rather, they decay one by one over a period of time. This is a random process: we can not predict exactly when a given nucleus will decay. But we can determine, on a probabilistic basis, approximately how many nuclei in a sample will decay over a given time period, by assuming that each nucleus has the same probability of decaying in each second that it exists.

The number of decays ΔN that occur in a very short time interval Δt is then proportional to Δt and to the total number N of radioactive nuclei present:

$$\Delta N = -\lambda N\, \Delta t \qquad \textbf{(30–3a)}$$

where the minus sign means N is decreasing. We rewrite this to get the rate of decay, and drop the minus sign

$$\frac{\Delta N}{\Delta t} = \lambda N. \qquad \textbf{(30–3b)}$$

In these equations, λ is a constant of proportionality called the **decay constant**, which is different for different isotopes. The greater λ is, the greater the rate of decay ($\Delta N/\Delta t$) and the more "radioactive" that isotope is said to be. The number of decays that occur in the short time interval Δt is designated ΔN because each decay that occurs corresponds to a decrease by one in the number N of nuclei present. That is, radioactive decay is a "one-shot" process, Fig. 30–9. Once a particular parent nucleus decays into its daughter, it cannot do it again.

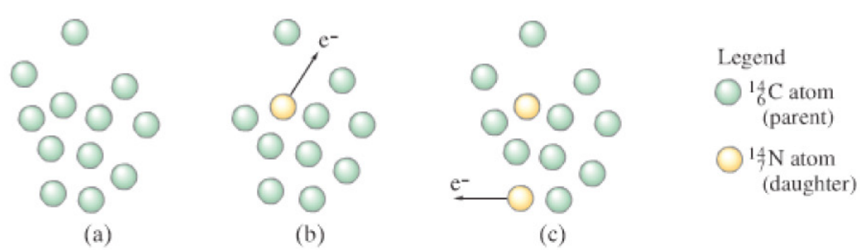

FIGURE 30–9 Radioactive nuclei decay one by one. Hence, the number of parent nuclei in a sample is continually decreasing. When a ${}^{14}_{6}$C nucleus emits the electron, the nucleus becomes a ${}^{14}_{7}$N nucleus.