

while the atomic mass number stays the same. Because the atomic number has changed, a new element, carbon 14 (atomic number 6, atomic mass number 14), is formed. The newly formed carbon 14 is rapidly assimilated into the carbon cycle and, along with carbon 12 and 13, is absorbed in a nearly constant ratio by all living organisms (Fig. 9-23). When an organism dies, however, carbon 14 is not replenished, and the ratio of carbon 14 to carbon 12 decreases as carbon 14 decays back to nitrogen by a single beta decay step (Fig. 9-23).

The ratio of carbon 14 to carbon 12 is remarkably constant in both the atmosphere and living organisms, and geologists assume that it has also been constant for the past 100,000 years. Comparing ages established by carbon 14 dating of wood samples with ages obtained by counting annual tree rings in the same samples yields slight differences (Fig. 9-24). It appears that the production of carbon 14 and hence the ratio of carbon 14 to carbon 12 has varied slightly over the past several thousand years, in part, because the amount of  $\text{CO}_2$  has varied. As a result, corrections in carbon 14 ages have been made to account for such variations in the past.

### Tree-Ring and Fission Track Dating Methods

In addition to radiometric dating, various other methods can yield accurate absolute dates. Two of the most common include tree-ring and fission track dating.

Tree-ring dating is a useful method for dating recent events. The age of a tree can be determined by counting the growth rings in the lower part of the trunk. Each ring represents one year's growth, and the pattern of wide and narrow rings can be compared among trees to establish the exact year in which the rings were formed. The procedure of matching ring patterns from numerous trees and wood fragments in a given area is referred to as *cross-dating*. By correlating distinctive tree-ring sequences from living to nearby dead trees, a time scale has been constructed extending back to about 14,000 years ago (Fig. 9-25). By matching ring patterns to the composite ring scale, wood samples whose ages are not known can be accurately dated.

The applicability of tree-ring dating is somewhat limited because it can only be used where continuous tree records are found. It is therefore most useful in arid regions, particularly the southwestern United States.

Fission track dating is a useful technique that can be applied in dating samples ranging in age from only a few hundred to hundreds of millions of years. It is most useful for dating samples between about 40,000 and one million years ago, a period for which other dating techniques are not particularly effective.

When a uranium isotope in a mineral emits an alpha decay particle, the heavy, rapidly moving alpha particle damages the crystal structure. The damage appears as small linear tracks that are visible only under a high-