Another beta decay event involves nitrogen-12, as follows:

$$^{12}_{7}\mathrm{N} \rightarrow \, ^{12}_{6}\mathrm{C} + \, ^{0}_{1}e \quad \text{(partial equation)}$$

This decay produces a positron, written as $^{0}_{1}e$. In this decay, the atomic number of the daughter nucleus is decreased by 1.

The superscripts and subscripts on the carbon and nitrogen nuclei follow our usual conventions, but those on the electron and the positron may need some explanation. The −1 indicates that the electron has a charge whose magnitude is equal to that of the proton but is negative. Similarly, the 1 indicates that the positron has a charge that is equal to that of the proton in magnitude and sign. Thus, the subscript can be thought of as the charge of the particle. The 0 used for the mass number of the electron and the positron reflects the fact that electrons and positrons are not nucleons; thus, their emission does not change the mass number. Notice that both subscripts and superscripts must balance in the equations for beta decay, just as in alpha decay.

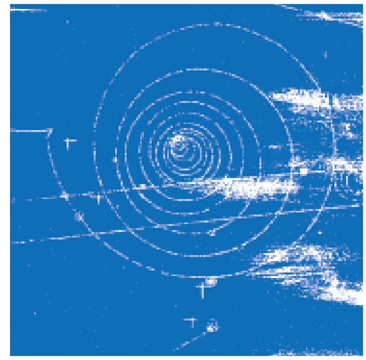

Figure 5
The spiral in this bubble-chamber image is the track left by a positron. This reaction took place in a magnetic field, which caused the positron to spiral as it lost energy.

Beta decay transforms neutrons and protons

A bubble-chamber image of a positron is shown in **Figure 5.** The emission of electrons or positrons from a nucleus is surprising because the nucleus is made of only protons and neutrons. This apparent discrepancy can be explained by noting that in beta decay, either a neutron is transformed into a proton, creating an electron in the process, or a proton is transformed into a neutron, creating a positron in the process. These two beta decays can be written as follows:

$$\begin{array}{l} ^{1}_{0}n \rightarrow \, ^{1}_{1}p + \, ^{0}_{-1}e \\ ^{1}_{1}p \rightarrow \, ^{1}_{0}n + \, ^{0}_{1}e \end{array} \quad \text{(partial equations)}$$

Decay events can be written in this way because other particles in the nucleus, much like the electrons around the nucleus, do not directly participate in the beta decay. The electrons and positrons involved in beta decay, on the other hand, are produced in the nuclear-decay process. Because they do not come from the shells around the nucleus, they cannot be ignored.

Neutrinos and antineutrinos are emitted in beta decay

Before we conclude our discussion of beta decay, there is one problem that must be resolved. In analyzing the experimental results of beta decay reactions, scientists noticed a disturbing fact. If carbon-14 beta decay actually occurred as described on the previous page, energy, linear momentum, and angular momentum would not be conserved. In 1930, to solve this problem, Wolfgang Pauli proposed that a third particle must be missing from the equation. He reasoned that this new particle, called a *neutrino,* is necessary to conserve energy and momentum. Experimental evidence confirmed the existence of such a particle in 1956.

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