EXPERIMENT 12

Annihilation Radiation Coincidence Studies with ^{22}Na

Scope

The annihilation radiation from a ^{22}Na source will be studied with an angular correlation apparatus. The β^+ particles from the source will be converted in a foil and the resultant .511 MeV annihilation quanta will be measured with two NaI(Tℓ) detectors. The angular correlation table that will be used for this experiment has provisions to fix one of the NaI(Tℓ) detectors and rotate the other one. With this system, we will verify the angular correlation of the annihilation radiation. These quanta will be shown to be emitted with an angular separation of 180 degrees, which is the only correlation that can conserve linear momentum for the two photons. This angular correlation will be verified by using three different coincidence arrangements.

Discussion

Figure 12.1 shows the decay scheme of ^{22}Na and the resultant NaI(Tℓ) spectrum. **Note:** The positrons are in coincidence with γ's from the 1.274 MeV (2+) state. The mean life of the 1.274 MeV state is 3×10^{-12} sec and therefore, from our timing situation, decay is immediate. A small fraction of the positrons (0.05%) decay directly to the ground state of ^{22}Ne. The Q_{EC} = 2.843 MeV shown in the figure is the excess energy that would be available if Electron Capture (EC) occurred to the ground state of ^{22}Na.

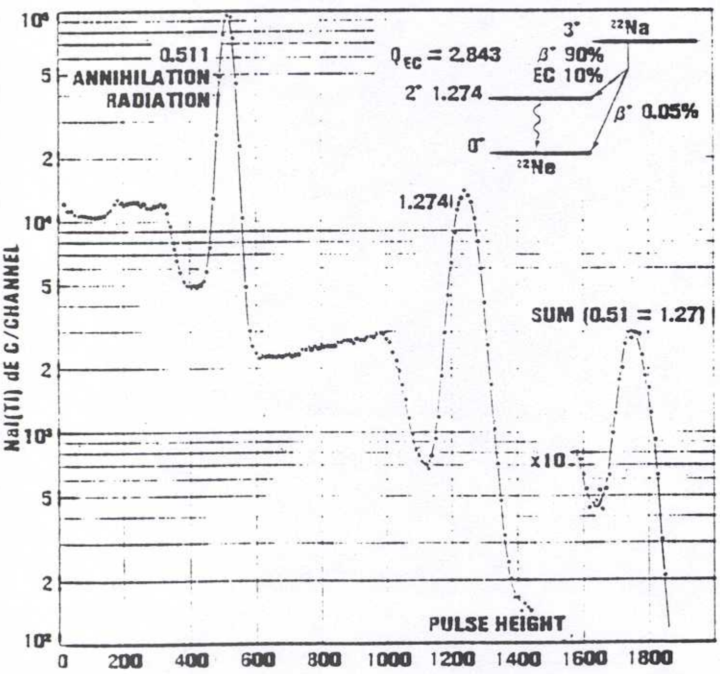

Figure 12.1. NaI(Tℓ) pulse height spectrum of ^{22}Na.

The β^+ end point energy to the ground state is 1.74 MeV. Most of the β^+ particles (90%) go to the (2^+) level at 1.274 MeV. The positron continuum to this level would have an end point energy of 0.466 MeV. Figure 12.2 shows what the distribution of β^+ particles would look like if we counted them with a β^+ pulse height analyzer.

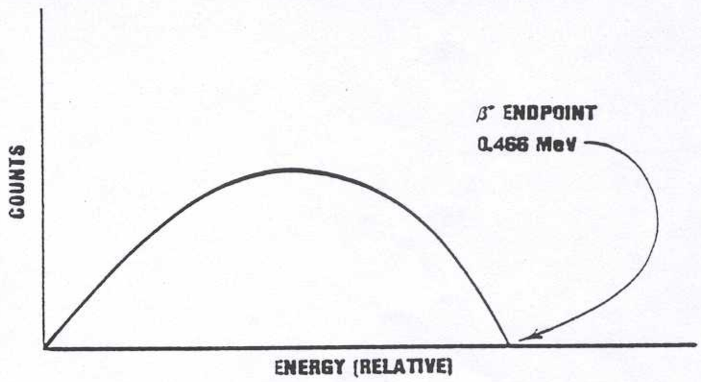

Figure 12.2. β^+ distribution from a ^{22}Na source.

In our experiment, we will encapsulate the ^{22}Na source with two converter foils to insure that most of the β^+ particles annihilate at the source. Basically the β^+ particles leave the source in an isotropic manner. When they enter the converter foil, they quickly (1×10^{-9} sec) lose energy by dE/dx in the foil. When a β^+ has essentially lost all of its energy, it finds an electron and captures that electron to form positronium which decays by the annihilation of the e^+ and e^- into two gammas. Conservation of momentum tells us that these gammas have to go off in opposite directions. This gives an angular separation of the gammas of 180 degrees. In this experiment, we will verify these conservation principles.

EXPERIMENT 12.1

Annihilation Measurements with a Multipurpose Coincidence Circuit

Discussion

From an electronic point of view, this experiment is quite similar to experiment 11. The student is urged to do experiment 11 before attempting this experiment. In the experimental procedure, we will assume that you are