

Chapter 4

Use with Section 1

ENRICHMENT**● Why do atoms combine?****Tiny Matter**

Neutrinos are subatomic particles. Trillions of them cross the Earth—and move through you—every second. They weigh less than a fraction of the mass of an electron. They are neutral. There are three types of neutrinos: electron-neutrinos, muon-neutrinos, and tau-neutrinos. Physicists have been studying neutrinos since the 1930s. The most important discoveries are listed below.

- 1930** Wolfgang Pauli hypothesizes that neutrinos exist.
- 1946** Shoichi Sakata proposes a scheme for the makeup of neutrinos.
- 1956** Clyde Cowan and Fred Reines discover neutrinos using a nuclear reactor.
- 1956-57** Bruno Pontecorvo, Shoichi Sakata, and other physicists suggest that neutrinos oscillate or change form.
- 1964** John Bahcall and Ray Davis propose measuring neutrinos from the sun.
- 1965** The first neutrinos are observed by Fred Reines and other physicists in a gold mine in South Africa.
- 1976** Scientists design new neutrino detectors in Hawaii.
- 1980s** First massive underground instrument for neutrino detection is built 2000 ft underground in a salt mine near Cleveland, Ohio. An experiment begins in Kamioka, Japan, in a zinc mine.
- 1986** Kamioka group observes solar neutrinos.
- 1996** Super-Kamiokande, the largest detector ever built, begins searching for neutrino interactions with a U.S.-Japan team.
- 1998** The Super-Kamiokande team analyzes 500 days of data. The team reports findings of oscillations or changes in form.

Answer the following questions, using complete sentences.

1. How would you describe the first 25 years of neutrino studies?

2. Based on the types of neutrinos, what kinds of changes do you think the scientists observed in 1998?

3. What properties of neutrinos make them especially difficult to study?

4. What could neutrinos tell scientists about the universe?
