

**Chapter 5**

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?

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

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

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4. What could neutrinos tell scientists about the universe?

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