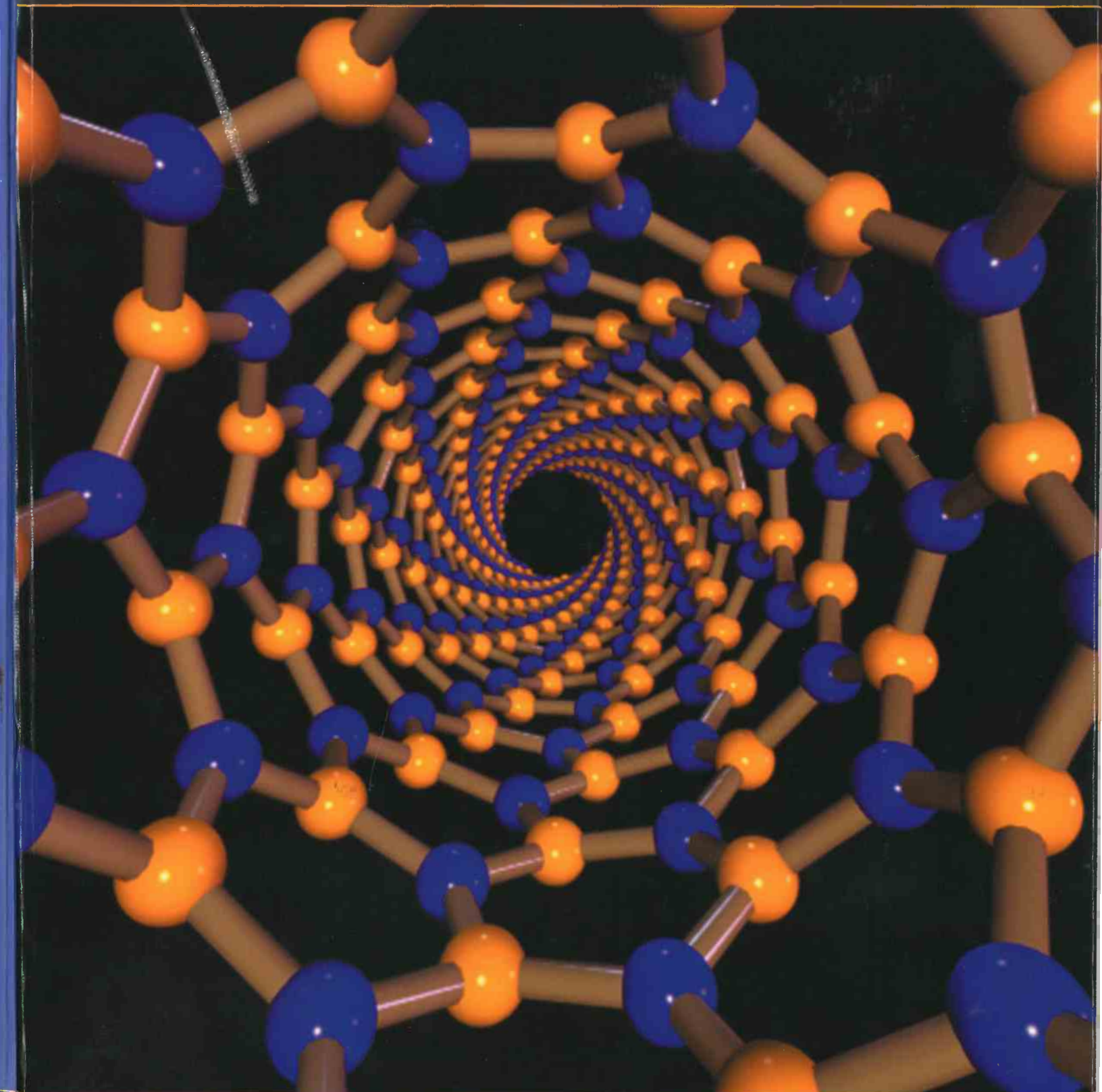


Fourth Edition

CHEMISTRY

Matter and Its Changes



BRADY • SENESE

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Chemistry

MATTER AND ITS CHANGES

4th
EDITION

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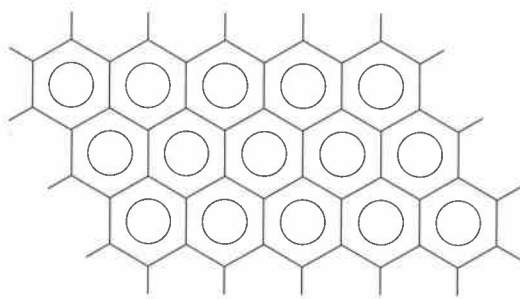
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evidence for atoms (see page 17). This instrument, which can only be used with electrically conducting samples, enables the imaging of individual atoms. What is very interesting is that it can also be used to move atoms around on a surface. To illustrate this, scientists have arranged atoms to spell out words (Figure 13.45). Although writing words with atoms doesn't have much practical use, it demonstrates that one of the required capabilities for working with substances at the molecular level is achievable.

To study nonconducting samples, a device called an **atomic force microscope (AFM)** can be used. Figure 13.46 illustrates its basic principles. A very sharp stylus (sort of like a phonograph needle) is moved across the surface of the sample under study. Intermolecular forces between the tip of the probe and the surface molecules cause the probe to flex as it follows the ups and downs of the bumps that are the individual molecules and atoms. A mirrored surface attached to the probe reflects a laser beam at angles proportional to the amount of deflection of the probe. A sensor picks up the signal from the laser and translates it into data that can be analyzed by a computer to give three-dimensional images of the sample's surface. A typical image produced by an AFM is shown in Figure 13.47.

Discoveries and progress in nanoscale materials

Among the new materials discovered through research in nanotechnology are carbon nanotubes, very thin tubes composed of rolled-up sheets of carbon atoms. Until the mid 1980s, only two forms of carbon were known, diamond and graphite. The structure of diamond, with its three-dimensional network lattice, was described earlier on page 559 and is shown in Figure 13.48a. **Graphite** is quite different from diamond and consists of layers of carbon atoms, each of which consists of many hexagonal "benzene-like" rings fused together in a structure reminiscent of chicken wire.



A fragment of a carbon layer in graphite.

In graphite, these sheets are stacked one on top of another, as shown in Figure 13.48b.

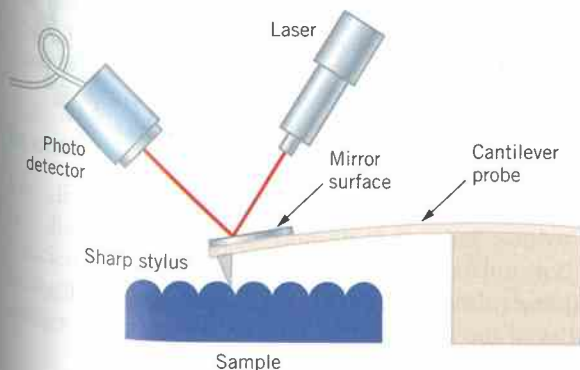


FIGURE 13.46 An atomic force microscope (AFM). A sharp stylus attached to the end of a cantilever probe rides up and down over the surface features of the sample. A laser beam, reflected off a mirrored surface at the end of the probe, changes angle as the probe moves up and down. A photo detector reads these changes and sends the information to a computer, which translates the data into an image.

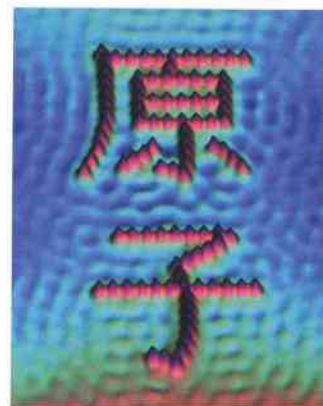


FIGURE 13.45 Atoms of iron on copper. Scientists at IBM used an STM instrument to manipulate iron atoms into the Kanji letters for "atom." The literal translation is something like "original child."