fundamental to the existence of life. Consider what conditions would be like if this force were either weaker or stronger.

If the nuclear force were slightly *weaker*, the protons would fly away from one another. Only elements such as hydrogen and possibly helium could form. The heavier elements could not exist because their protons, like the male lions, could not be brought together. Without the heavier elements, especially carbon, the possibilities of life become highly remote.

Conversely, if the strength of the nuclear force were slightly *stronger*, then all atomic nuclei would have to contain a minimum of several particles because a single proton would attract others. This would mean that hydrogen could *not* form. Without hydrogen there could be no water (H_20). Life without water is difficult to conjure by even the best of wizards.

The Electromagnetic Force. Another basic value we take for granted is the force of attraction between a proton and an electron (the electrical attraction between positive and negative charges). If this force of attraction were much stronger, then the electrons orbiting around the nucleus of an atom would be pulled into the nucleus and scrambled with the protons and neutrons already there. Without electrons in the outer shell of an atom to share and exchange with other atoms, it is hard to see how molecules could form (see figure 2.3). Stable chemical bonding would become impossible, and it would be difficult for life as we know it to exist under such circumstances.

Let us now turn from the infinitesimal world of the atom and its highly critical forces to consider the gigantic world of the Cosmos. Are there critical values imposed that might affect the basic formation of stars and planets?

The Cosmological Conditions. I live about fifteen miles from Vandenberg Air Force Base. Space probes and satellites are frequently launched in full view of my front porch. At night the spectacle is something to behold. The rockets leave a trail of white, orange, and blue as they soar into the heavens on their directed mission.

The space engineers at Vandenberg insist that it is very important to power these rockets properly. The amount of fuel is critical. The rate of burning is carefully calculated and designed. If not enough power is put into a rocket, it will go only a short way and then crash to Earth under the pull of gravity. Conversely, if too much initial power is put into a rocket, it will either destruct or soar off into the void of space, never to be heard from again.

The cosmological condition that determines the rate of expansion

FIGURE 2.4

The launching of the Columbia space vehicle for its final orbital flight test, June 27, 1982. The attached solid-rocket boosters fire to lift the vehicle into a precise circular orbit. (Courtesy NASA.)