Chemistry's First Law

Historical Perspective

The notion that "nature abhors a vacuum"—meaning that there is no such thing as "empty space"—was proposed by the Greek philosopher Aristotle, whose word was unchallenged for nearly 2000 years. Then, in the mid-1600s, a new breed of thinkers known as *natural philosophers*—what we now know as "scientists"—began testing the long-held assumption that all space must contain matter. These investigations were some of the earliest experiments with gases, and they led to the discovery of the first empirical principle of chemistry, Boyle's law.

Overturning an Ancient Assumption

The first scientist to demonstrate the existence of a vacuum was Evangelista Torricelli. In 1643, he showed that when a glass tube that was 3 ft. long and about 1 in. in diameter was sealed at one end, filled with mercury, and inverted in a container full of mercury, the mercury in the tube fell to a height of about 30 in. above the level of mercury in the container. Some thinkers remained skeptical, but it was generally accepted that the space between the mercury and the sealed end of the tube was indeed a vacuum.

▲ *Evangelista Torricelli invented the mercury barometer.*

Torricelli then turned his attention to how the mercury in the glass tube of his apparatus was supported. The fact that liquids exert a pressure on objects immersed in them inspired him to hypothesize that a "sea of air" surrounded Earth. He further hypothesized that the air exerted pressure on the mercury in the container and thus supported the mercury in the column.

Support for the New Theory

Although the idea of an atmosphere that has weight and exerts a pressure on the objects within it seems obvious today, it was a radical theory at the time.

To test the effects of the atmosphere, Robert Boyle, one of the period's great scientists, had his talented assistant, Robert Hooke, create a piece of equipment that would revolutionize the study of air. The apparatus was an improved version of a pump designed by the German experimenter Otto von Guericke; the pump had a large receptacle in which a partial vacuum could be created.

Boyle placed Torricelli's setup, known today as a *barometer*, in the receptacle of the pump and observed the mercury column as he reduced the pressure around it. The height of the mercury decreased as the pressure surrounding the mercury in the container dropped, strongly supporting Torricelli's atmospheric theory.

Using Hooke's pump, Boyle performed additional studies that verified the idea that air exerted pressure and had weight. Boyle's experiments also led to the important conclusion that air was elastic: that is, it could expand and contract. Boyle discovered the fundamental law that bears his name during an investigation into air's elasticity.

An Ingenious Experiment

In response to a criticism of his findings, Boyle performed an experiment to show that air could be compressed to a pressure greater than that of the atmosphere. First, he prepared a glass J-tube with the short end sealed off and the long end left open. Then, he poured mercury into the tube, making sure that the levels in the two ends were the same and letting air travel freely between the ends, to ensure that each column was at atmospheric pressure.

Then, by pouring more mercury into the long end of the tube until it was about 30 in. above the level of mercury in the short end, Boyle exposed the trapped air to about twice as much atmospheric pressure. He observed that the