BOYLE'S LAW AND A HIGH-FLYING ELMO

I had an amusing little encounter with a prospective scientist last time I was flying home from Toronto. Sitting next to me was a small boy who was playing with several bags of peanuts, the bribe he'd extracted from the flight attendant in return for being quiet during the flight.

The boy played happily with the unopened bags throughout the journey, but his face took on a perplexed expression as we landed. The bags had noticeably decreased in volume, prompting the youngster to ask his mother where the peanuts had gone. She had no answer and told her son to stop asking so many silly questions. The lady was obviously unaware of Boyle's Law.

Robert Boyle was born in 1627, in Britain, and was eventually sent off to study at Eton. One evening, while he was outside watching a spectacular display of lightning, he began to wonder why he had not been struck. In a rather unscientific fashion, he concluded that God must have reserved him for some special task. From that moment on, Boyle dedicated himself to demonstrating God's glory by unraveling the secrets of nature.

Boyle became interested in an experiment that had been performed in Germany by Otto von Guericke. In the early part of the seventeenth century, von Guericke had heated a hemispherical copper bowl filled with water until the water boiled. He then fitted a second bowl over the first one, leaving just enough space at the joint to let steam escape. After the heat source was removed, von Guericke discovered that the bowls had become sealed so tightly that two teams of horses couldn't pull them apart. The steam had driven out the air, and when the steam inside the sphere condensed back into a liquid, a partial vacuum was created. The two hemispheres were now held together by the outside air pressure.

All this may sound a little complicated, but the fact is that most of us have carried out a version of this classic experiment in our kitchens. If you remove the lid from a boiling pot and place it on the counter, you'll likely find that it sticks like glue. The trapped steam condenses and creates a vacuum. It isn't surprising that Boyle was fascinated by this effect and was inspired to study the relationship between air and pressure.

Boyle's classic experiment was a marvel of simplicity. He took a J-shaped tube sealed at the short end and proceeded to trap air inside by filling the tube with mercury. He found that the volume of the trapped air varied with the amount of mercury he used and formulated the law that is now studied by every high-school student around the world: the volume of a gas is proportional to the pressure exerted on that gas.

This is exactly what my young traveling companion had experiences. As the airplane gained altitude and the pressure in the

cabin decreased, the volume of the peanut package increased. On landing, he could observe the reverse effect.

I didn't feel it was my role to enlighten the young man and his mother about the subtleties of Boyle's law, but this was not the case when I took my daughter to see *Sesame Street Live*. Needless to say, such an outing involved the purchase of a souvenir – in this case, a helium-filled Mylar balloon in the shape of Elmo. Also needless to say, the balloon didn't make it back to the car. Its escape into the great beyond of course elicited tears, but it also prompted a question about what would now happen to Elmo. And this was not such an easy question to answer.

If the balloon had been made of rubber, it would have expanded in size as it floated up in response to the decreasing outside pressure. But temperature decreases with altitude, and gases contract with lower temperatures; this effect may then be expected to shrink the balloon. We therefore have two factors working in opposition. Calculations, however, show that the expansion due to reduced pressure is more significant, and that as the balloon rises it should eventually burst.

This was probably not the fate of the Elmo balloon. Mylar is made of polyester coated with a thin layer of aluminum. It was originally developed to serve as a heat-reflective material in the space program. Mylar does not have elastic properties, but it is extremely strong – so Elmo could rise to great heights without bursting.

In all likelihood, the helium would eventually diffuse through the plastic membrane, and the collapsed balloon would fall back to earth. This, while certainly a comforting thought, did not nix the demand for a replacement Elmo: Elmo number two will exists and is adored, although it is in rather anemic shape due to the loss of helium by diffusion.

Boyle's law has some unusual connections as well. The *New England Journal of Medicine* reports that a lady tourist showed up in the emergency room of a hospital in Frisco, Colorado, complaining of a "swishing" sound in her breasts. X-rays quickly revealed the source of the problem. It seems that the patient had a saline breast implant, which is basically a plastic bag filled with saltwater. Such implants, however, are not completely filled with water and therefore have air pockets. The lady had come to high-altitude Colorado from sea level, and according to Boyle's law, the air pockets had expanded due to the lower external pressure. The water inside now had room to swish around.

This is a true story, unlike the tale going around about the flight attendant who purchased an inflatable bra and experienced an explosion after takeoff. Although such devices do exist, the small change in volume due to a decrease in cabin pressure is not enough to cause such a spectacular effect. The story is an urban myth that deserves to be deflated.