THE FOUR ELEMENTS

A Chemist and an Artist Interpret the Essences of Classical Greece

BY ROALD HOFFMANN AND VIVIAN TORRENCE

EARLY ON IN MURIEL SPARK'S 1961 novel *The Prime of Miss Jean Brodie,* the title character, an eccentric, fascistophile Edinburgh schoolmarm (now merged in collective memory with Maggie Smith) burrs the following: "Art and religion first; then philosophy; lastly science. That is the order of the great subjects of life, that's their order of importance."

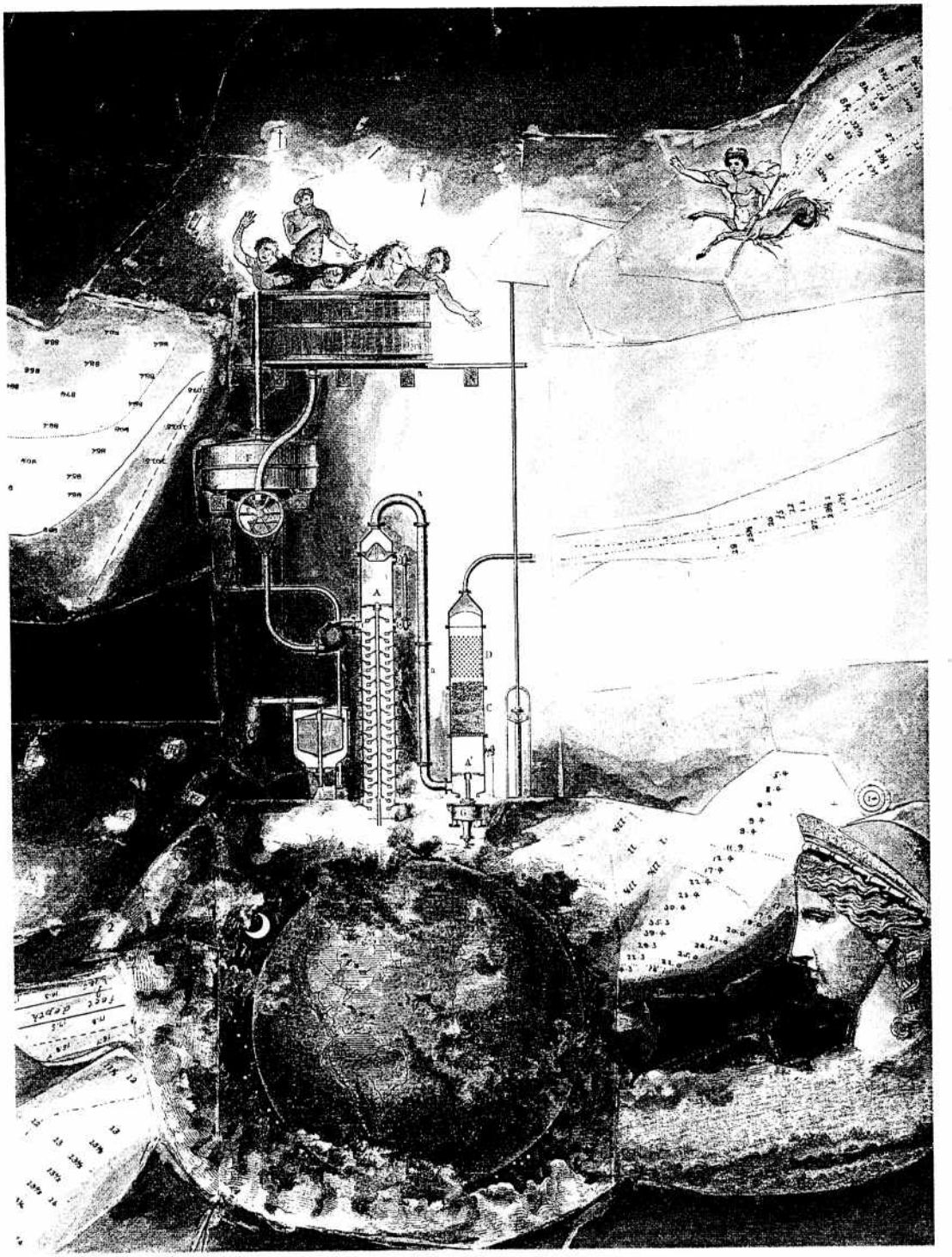
Deferring for the cafés any debate on items one, two or three, many people would surely applaud Miss Brodie for her choice of number four. In so doing, some of them might wince to recall how, as embryonic writer-painter-actor-waiters slouching and sliding under a black Formica tabletop in some compulsory laboratory, they used to wonder: What in this sterile purgatory could remotely interest anyone sans madras shirt and plastic penholder? There is creativity, there is culture, there is *life.* And for the pasty-faced drones of the world there is that other thing, the *S* word.

But every now and then (the Renaissance leaps to mind) one finds evidence that the lines between science, art, culture, et cetera, are a little fuzzier than some people might think. It can even be argued that doing science is nothing if not a creative act—that, in a sense, the theory of relativity came from pretty much the same place as did *Guernica, The Rite of Spring* and *Ulysses.*

Hence *Chemistry Imagined: Reflections on Science,* by the Nobel laureate chemist Roald Hoffmann and the artist Vivian Torrence. The spare but rich volume of words and pictures introduces general readers to the history and mystery behind all the formulas and the test tubes. In spirited bursts of text Hoffmann—best known for applying quantum mechanics to the study of chemical reactions—filters his field through the soul of a poet, skirting deftly what he calls the "deadening jargon" of science. Here he weeps for Madame Curie; there, in the space of a page, he leaps from William Blake to Niels Bohr, or from the music of Elliott Carter to a molecule of hemoglobin. And Torrence, whose fantastic, finely wrought collages are like windows on the working intellect, matches Hoffmann step for step. Inspired, she says, by "nature's layers of reality," Torrence captures the sheer wonder of the scientific enterprise. Together she and Hoffmann offer a beguilingly original take on chemistry, the art—yes, art—of making transformations. Or as Torrence has put it, the quest to "find out what *stuff* is."

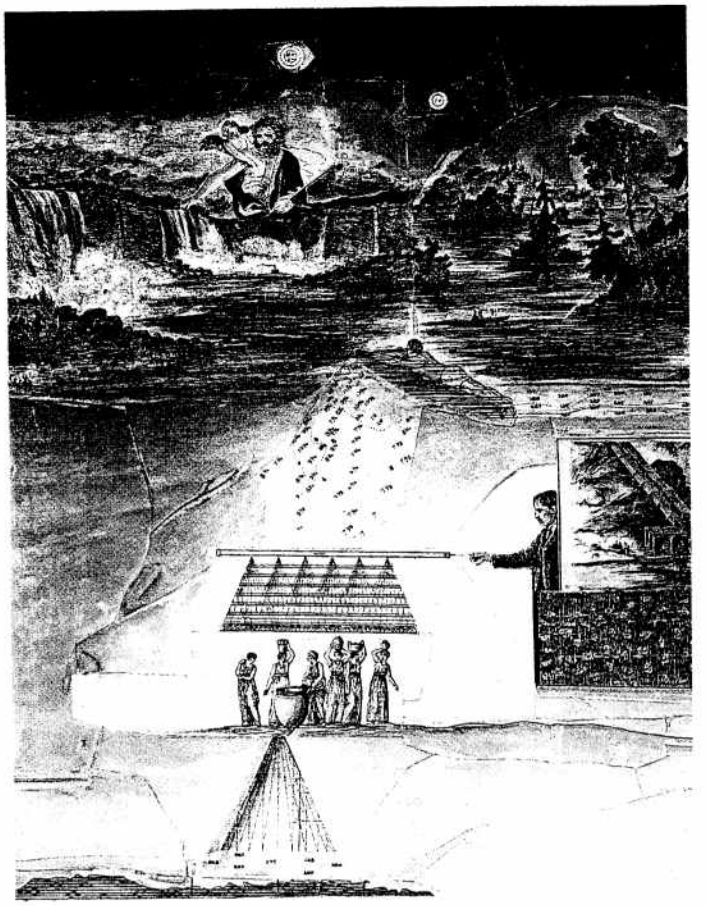
The following excerpts are from Hoffmann and Torrence's treatment of air, water, fire and earth, the four kinds of "stuff" in which the ancient Greeks vested their still-trenchant idea that matter can be reduced to a small set of elements.

—RICHARD JEROME



Greek Air

When Jan Baptista van Helmont, a seventeenth-century Dutch scientist and alchemist, introduced the word for gas, he derived it from chaos, an ancient Greek term describing the unformed mass of the universe before the creation of the gods. In English, of course, chaos has come to mean confusion and disorder—which, for scientists, have no negative connotation. In fact, entropy, the tendency to maximize disorder, is the driving force for the spontaneous act in chemistry. Gases, including air, are indeed in a chaotic state: molecules in constant motion, moving randomly, colliding frequently. Molecular motion is heat: the hotter the gas is, the faster its molecules move. And, on average, molecules move rather quickly—the velocity of air molecules, for instance, is typically around 1,000 miles an hour, a little greater than the speed of sound.

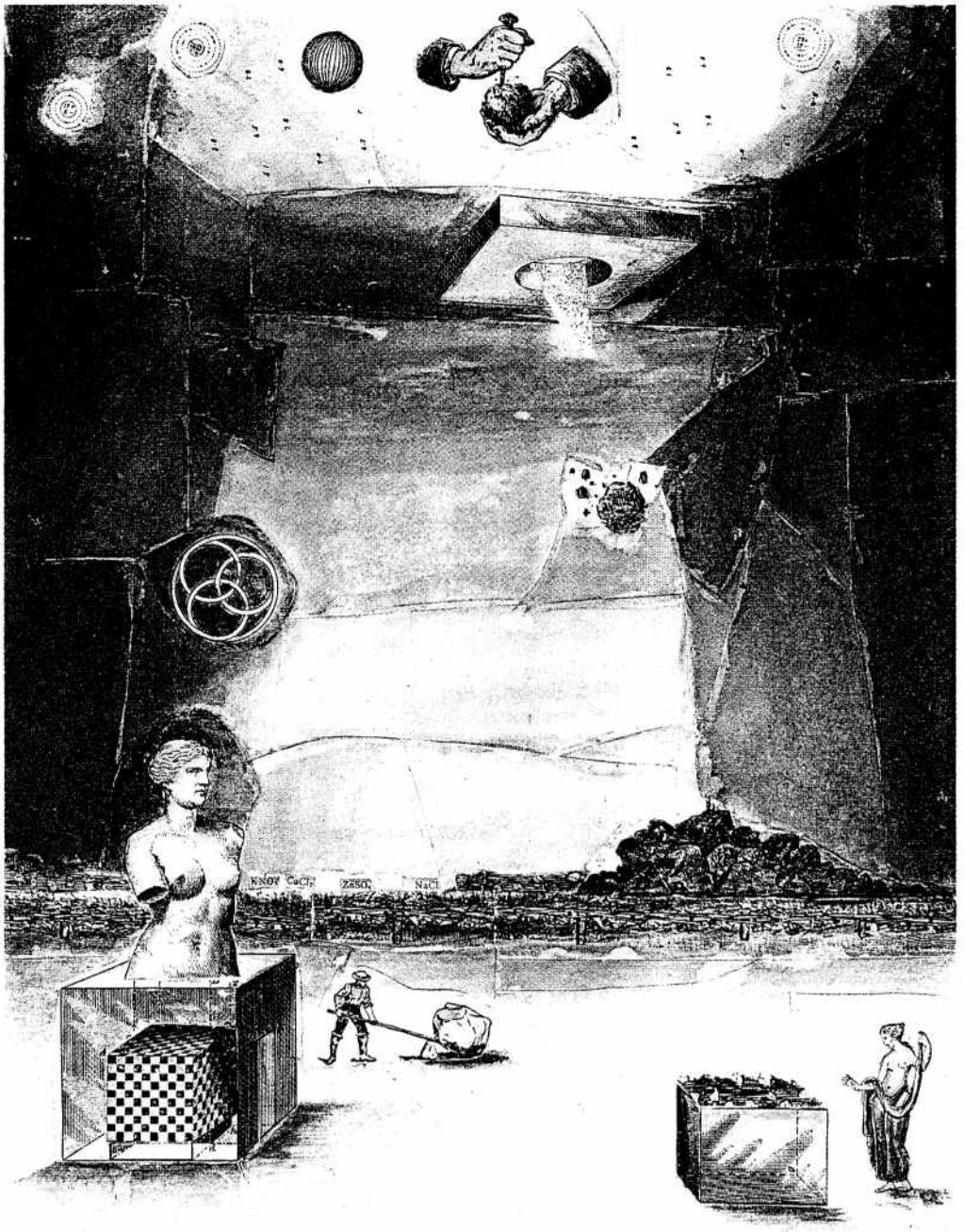


Greek Water

If the earth were impervious to water, our lives would be different. But the earth is leaky; groundwater that saturates soil and rock formations supplies much of our drinking water. Water moves down through sandy soil and fractured rock, seeking discharge at lower depths in springs, wells and wetlands. Controlled leakage figures importantly in the transport of water across biological membranes, including the cell membrane. A general principle of societies and the human cell is that economy of function is achieved by sequestration and communication. One segregates to accomplish a task; yet the partitions have to be just leaky enough to allow real, and molecular, commerce.

Greek Fire

Chemistry was deluded for a hundred years by the false theory, formulated in the eighteenth century, that the essence of fire was a substance called phlogiston. When matter burned, it gave off phlogiston. Wood was full of it, ashes empty. The standard argument against phlogiston theory was that substances gain weight when they rust and when they burn. So how could something, phlogiston, be given off if the weight increased? That detail did not bother the proponents of the theory because they saw chemistry as a study of intrinsic qualities. Weight hardly seemed worth worrying about. "You do not surely expect that chemistry should be able to present you with a handful of phlogiston," wrote the English chemist Richard Watson in 1781. "You may just as reasonably demand a handful of magnetism, gravity or electricity."



GREEK EARTH

What is the earth made of?

Well, it matters what pretty piece of real estate you choose. Much of the planet's inaccessible molten core is iron. At the surface are mostly minerals, including vast quantities of silicon oxides and many aluminum-containing minerals as well. Much of the earth's oxygen is tied up in minerals, not in the atmosphere. All over the earth this wealth of elements seems to show itself in amorphous-looking rocks, soils, plants and flesh. But here and there miners came across something else: crystals, near-perfect latticeworks of atoms marching toward infinity, are testimony to the symmetry of the underlying interatomic forces, unusual only in that their macroscopic order also manifests itself in their macroscopic appearance. All those other seemingly inchoate things—granite, a fern—are also ordered within.

Among Australian aborigines shamans are initiated by being fed quartz crystals. Those "stones of light" are pieces broken away from the heavenly throne. They enable the shaman to see into space, into matter, into the soul.