Robert Bunsen . . . more than a burner design

by *Derek Davenport*

Some men are fated to be remembered for a single achievement—and not always their most glorious. Who recalls Custer's *first* stand? In chemistry, Erlenmeyer lives on as a flask, Claisen as a condenser, Gooch as a crucible and, above all, Bunsen as a burner. In remembering him thus, we do scant justice to Robert Bunsen, one of the greatest and most influential of 19th-century chemists. Besides, the design of the famous burner was not entirely new and Bunsen's instrument maker played as large a part as he in its perfection.

Robert Bunsen (1811–1899) was born in Gottingen, Germany, the son of the chief librarian and professor of modern languages at the university. A precocious student, he received his doctorate degree at the age of 19. For the next three years he traveled and studied in Germany, France, and England before embarking on his long and illustrious academic career.

His first major research was on *cacodyls,* compounds containing carbon, hydrogen, and arsenic. The most important of these proved to possess the molecular formula, $C_4H_{12}As_2$. These compounds were all highly poisonous, often spontaneously flammable, and were possessed of smells to make a billy goat blush. Bunsen described one of these compounds thus: "The smell of this body produces instantaneous tingling of the hands and feet, and even giddiness and insensibility. . . It is remarkable that when one is exposed to the smell of these compounds the tongue becomes covered with a black coating, even when no further evil effects are noticeable."

From such unlovable compounds Bunsen was able to establish one of the most important principles of organic chemistry—that in some chemical reaction sequences a particular group of atoms (in this case a CH_3- or methyl group) may survive totally untouched. This principle was one of the keys to the developing science of organic chemistry, which was shortly to enter upon its golden age. But when an explosion of cacodyl cyanide caused loss of sight in his right eye, Bunsen decided, golden age or not, to swear off organic chemistry for life. His remaining labors were, in the broadest possible sense, concerned with chemical analysis.

An expert glass blower, Bunsen perfected methods for manipulating and analyzing gases in a quantitative way. He then applied these methods to the improvement of blast furnaces, to the analysis of gases from Icelandic volcanoes, and to the photochemical and combustion behavior of mixtures of gases. A minor by-product of this research was the perfection of the immortal burner. He never patented his invention and indeed mentioned it only in passing in some of his papers.

In 1855, the city of Heidelberg was first illuminated by coal gas. Bunsen was in the process of designing his new laboratory (much of his previous work had been done in an abandoned monastery), and he was eager to employ the gas, not so much to illuminate the laboratory, but to replace the old, inconvenient, and sooty furnaces then in use for heating reaction vessels. He drew on earlier work by Humphry Davy and Michael Faraday in England and on designs by Aimé Argand and others in France, all of whom had tried to perfect a hot and smokeless gas flame. Working with his instrument maker, Peter Degasa, Bunsen devised the burner we know today in which the essential premixing of air and gas is controlled by a rotating sleeve. The trick was to premix the gases in such a way that the flame did not "strike back" even in the absence of the wire gauze used in the Davy–Faraday miner's safety lamp. Bunsen and Degasa succeeded admirably.

Bunsen was the first to use carbon (graphite) cathodes and zinc anodes in a battery, with chromic acid serving as electrolyte and depolarizer. With a bank of these batteries, he purified many of the known metals in bulk—chromium, magnesium, barium, strontium, cerium, and lanthanum. And in the early 1860s he discovered the remaining alkali metals, cesium and rubidium, in certain mineral waters.

Forty tons of mineral water had to be processed to produce 16.5 g of cesium and rubidium chlorides. The names of these two new elements—cesium from the Latin *caesium* or sky blue and rubidium for the Latin *rubidus* or dark red, refer to the most prominent lines in their flame spectra. This in turn brings us to Robert Bunsen's greatest contribution to chemistry—chemical spectroscopy.

About 1860, Bunsen, in collaboration with his physicist colleague, Gustav Kirchhoff, carried out a series of investigations which founded the science of chemical spectroscopy. Every element has its spectroscopic fingerprint. The bluish appearance of the cesium flame is traceable to an emission of radiation of wavelength 455.5 nm; the deep red color of the rubidium flame to an emission of radiation of wavelength 780.0 nm. Furthermore, Bunsen and Kirchhoff showed that "cold" atoms absorb light at *exactly* those wavelengths which they emit when "hot." Thus the dark lines in the spectrum of the sun (Fraunhofer lines) were explained by selective absorption in the "cold" outer layers of the sun of the continuous radiation produced by the nuclear reactions in the interior (see "Star Born," p. 6). All our present knowledge of the chemical constitution of the stars has come, and will probably always come, from spectroscopic observation, a science we owe to Bunsen and Kirchhoff.

And what part did Bunsen's burner play in all these marvels? Very little, though it did provide a convenient way of generating the high temperature needed to produce the flame emission spectra. Would Bunsen mind being remembered for a minor practical invention? Probably not, for he was an eminently practical man. Better to be remembered for a living burner than a dead theory.

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You are an ecologist, working for the Fish and Wildlife Service. Your boss gives you a challenging new assignment: Determine why the fish are dying in a certain mountain lake. She is concerned because the problem may threaten a fish hatchery on the same lake. This is a simulation called "Lake Study," running on a personal computer, but it is more than a game because it combines the principles of science with real-world uncertainties and foul-ups. There is no "right" way to approach the fish-kill problem, and you must decide how to proceed.

Suppose you decide to collect samples of lake water. Press the proper key and the computer displays a bird's-eye view of the lake with a boat at a dock. You must steer the boat to the locations where you wish to take samples. Then, you may choose to go to the laboratory. A keystroke later you are in the lab, which has a flame spectrometer, a gas chromatograph, and (thankfully!) a technician to operate them. The lab tests tell you the concentrations of pesticides, heavy metals, and oxygen. Are these levels too high . . . too low? A trip to the library (press another key) provides some of the answers. Now you can form a hypothesis about what is killing the fish. But the boss demands *proof* and asks for some lab experiments with fish. For each fish tank you must specify the temperature, number of fish, and concentration of pollutants. Later you decide to consult a colleague who points out that you forgot to test the water for mercury. Rats! . . . Head back to the lake for more samples.

"Lake Study" requires no prior knowledge of environmental chemistry, but rewards users who organize data, form concise hypotheses, and design good experiments. The program runs on a 48K Apple II+ or IIe. "Lake Study" was written by David Whisnant, associate professor of chemistry at Wofford College, Spartanburg, S.C. A copy may be obtained by ordering Apple Disk #18 from Project SERAPHIM/*Chem Matters*, John Moore, Department of Chemistry, Eastern Michigan University, Ypsilanti, Mich. 48197. Send a self-addressed mailing label (or file card) and a check for $4 made out to Project SERAPHIM. You may wish to ask for the free SERAPHIM catalog, which lists inexpensive chemistry software for several types of computers.