The Poets of Chemistry

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How the scientific musings of the writer Goethe led to basic concepts of catalysis and the isolation of caffeine.

As we have seen time and again, the line between art and science is a fine one. In many cases, events that started out as an artistic exploration have led to great moments in science, and likewise, scientific exploits can be appreciated for their intrinsic beauty. This was never more the case than in the three intertwined lives of Johann Wolfgang Goethe, Johann Wolfgang Döbereiner, and Friedlieb Ferdinand Runge, German chemists and philosophers of the late 18th and early 19th centuries.

IMAGES: GOETHE, THE NORTH AMERICAN FICHTE SOCIETY; DÖBEREINER & RUNGE, EDGAR FAHS SMITH COLLECTION, UNIVERSITY OF PENNSYLVANIA LIBRARY

The Metamorphosis of Goethe

Born in Frankfurt am Main, Germany, on August 28, 1749, to an Imperial Councillor and mayor's daughter, Goethe's early life was one of pomp and circumstance that led to the writings for which he is best known. But being a man of many talents, Goethe was drawn to a multitude of topics, and during his law studies in Strasbourg, France, in 1770, Goethe attended lectures in anatomy, surgery, and chemistry, a habit that he repeated in several other cities throughout his life.

A true Renaissance man, Goethe's fascination with science led him to produce a series of treatises on everything from botany (*The Metamorphosis of Plants*, 1797) to geology (*On Granite*, 1784) to meteorology (*Toward a Theory of Weather*, 1825). As a matter of fact, his treatise on color—*Theory of Color* (1810)—served as the basis of an artistic movement.

In sharp contrast with Newton's theory that white light is composed of different wavelengths of colored light, Goethe held with the classic notion that cool blue colors represented a lightening of black and warm red colors were a darkening of white. He expressed himself poetically with the line, "Colors are the deeds and sufferings of light."

Scientifically, Goethe was an "experientialist" in that he believed that the scientist was not merely a passive observer of the universe but a part of that universe with which he shared a reciprocal relationship.

"The thinker makes a great mistake when he asks after cause and effect. They both together make up the indivisible phenomena," he said. Thus, Goethe's science largely flew in the face of the reductionism of contemporaries such as Newton.

Goethe's scientific philosophy was reflected in some of his poetic writings, including the 1809 publication, *Elective Affinities*, a novel that describes the impossible relationship of an aristocratic couple who bring two others into their lives and unwittingly become pawns in their own immoral game. The novel might, to some extent, be autobiographical: Goethe was married to one woman but was living with his mistress at the time. The title of the novel reflects the then-prominent chemical concept of the perfect molecular attraction.

Proving His Metal

Goethe's attraction to the sciences led him to associate with many of the leading scientific minds of the time, some of whom he promoted through his connections with various European universities. One such person was Johann Wolfgang Döbereiner, a German pharmacist whom Goethe helped get a position in chemistry at the University of Jena in Germany in 1810.

Born on December 13, 1780 in Hof an der Saale in Bavaria, Döbereiner's life was the perfect antithesis to that of Goethe. The son of a coachman who was unable to afford much schooling, Döbereiner was literally a self-made man who, on his mother's urging, took up life as a pharmacist, apprenticing for several years with an apothecary. This position gave him the opportunity to attend several lectures on the sciences, but did not afford him his own pharmacy. Instead, he opened an agricultural produce business where he proceeded to develop his own pharmaceutical preparations. Reports on his work in a chemical journal brought him to the attention of other chemists, and when his career had reached its lowest point, he received the offer from the University of Jena.

One of Döbereiner's earliest contributions to chemistry was the result of his interest in elemental behavior. In 1817, Döbereiner noticed that barium, calcium, and strontium had very similar chemical properties and he grouped these elements into a triad. When he then ordered the elements on the basis of their atomic masses, he noticed an interesting coincidence: the mass of the middle element (strontium-87.6) was roughly halfway between the masses of the first (calcium-40.1) and the third (barium-137.3). He then looked to see if this held true for other elements of similar character and found that indeed bromine (79.9) was roughly halfway

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between chlorine (35.5) and iodine (126.9). Such triads held for many groupings of elements. Döbereiner's contribution was an early component of the periodic table that was later developed by Dmitrii Mendeleev.

Döbereiner was predominantly interested in metals and specifically in the chemistry of platinum. In 1820, Edmund Davy, a cousin of famed chemist Humphry Davy, generated a compound called platinum black by reducing platinum sulfate with boiling ethanol. He noticed that the platinum metal became white-hot when it reacted with the ethanol vapors. A year later, Döbereiner repeated Davy's experiments but also noticed that the ethanol was oxidized to acetic acid. Similarly, Döbereiner determined that when tartaric acid, water, and sulfuric acid are distilled in the presence of black oxide of manganese, formic acid is produced.

But it wasn't until 1823 that Döbereiner gained worldwide fame when he noted a strange property of metallic platinum. He found that when sulfuric acid acts on zinc, it creates hydrogen gas that can be directed to sponge platinum. The metal catalyzes a reaction between hydrogen and atmospheric oxygen, and the resulting energy is absorbed by the metal and released as heat. Döbereiner noted that if a stream of hydrogen was directed at the platinum, the metal could become sufficiently heated that it would ignite the hydrogen stream, creating, in essence, a portable lighter.

The creation of Döbereiner's lighter created quite an international stir and prompted Swedish scientist Jöns Jacob Berzelius to write in 1823, "From any point of view, the most important and, if I may use the expression, the most brilliant discovery of the last year is, without doubt, that . . . made by Döbereiner." Berzelius later coined the expression that labeled the reactions that Döbereiner and his contemporaries were witnessing: metal-based chemical catalysis.

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Glazed Eyes and Blue Dyes

Working in Döbereiner's laboratory was a young student named Friedlieb Ferdinand Runge. The third child of a minister, Runge was born in 1794 in a small town south of Hamburg. Runge's interest in science developed early. During one experiment he conducted as a teenager, he was preparing an extract from the nightshade or belladonna plant and a drop of the extract splashed in his eye. He became fascinated by the resulting dilation of his pupil. Ten years later, in 1819, while working for Döbereiner, Runge was asked to repeat the dilation experiment on his cat for Goethe, who was visiting the lab.

Goethe was impressed by Runge's trick and as the younger man rose to leave, the poet offered him a prize of rare coffee beans, suggesting that Runge should try to determine what compound within the beans gave them their intoxicating quality. Runge accepted the challenge and within months had successfully isolated the active ingredient, caffeine, a member of the purine family. In 1927, Oudry isolated the compound theine from tea, and 11 years later, Jobet showed that theine was the same chemical as caffeine.

Runge's success continued unabated as he proceeded to isolate the compound from the belladonna extract that had earned him Goethe's attention. The chemical fell into a class of compounds known as alkaloids and was later given the name atropine. A muscle relaxant, atropine relaxes the eye muscles, thereby causing dilation.

Runge's experiences with purine chemistry also led to the isolation of quinine, a compound that became crucial to modern warfare because of its antimalarial properties. However, whether quinine was first isolated by Runge or by Pierre Joseph Pelletier and Joseph Bienaimé Caventou is still a point of contention among scholars.

After completing his medical studies at Jena, Runge moved to the University of Berlin where he earned a doctorate in chemistry in 1822, and he eventually landed a position as a chemistry professor at the University of Breslau. By 1831, however, he had tired of the academic life and moved into a chemical factory in Oranienberg to work on synthetic dyes. Eventually, he was the first to make aniline blue from coal tar.

Runge and his contemporaries continued to work with coal tar, extracting a great variety of chemicals in the process, including phenol and pyrrole. These compounds provided the basis for many industries that generate products such as dyes, cosmetics, drugs, paints, and flavorings. It was also during this time that Runge began to notice a behavior of these dyes: As they moved through paper, they separated into several component parts. This observation was a pioneering moment in the development of paper chromatography.

But Runge's burgeoning chemical career came to a screeching halt in 1856, when the widow of the factory owner threw Runge out of the plant, evicting him from his home and limiting his pension, in a dispute over the rights to a process that Runge had developed for the manufacture of synthetic guano (fertilizer). He died in 1867 in relative obscurity and poverty, only to be recognized posthumously by the German Chemical Society two years later.

Thus, the poetical musings of Goethe stretched not only to Faustian legends but also planted the seeds of the periodic table, concepts of metal-based catalysis, and the isolations of caffeine, atropine, and the blue dye of aniline.

Suggested Reading

Weinberg, B. A.; Bealer, B. K. *The World of Caffeine;* Routledge: New York, 2001.

Treatise on Goethean science; www.physics.vanderbilt.edu/courses/sth209/index.html.

Johann Wolfgang Döbereiner's Feuerzeug, written by George Kauffman, provides extensive detail on the development of Döbereiner's lighter and can be found at www.nesacs.org/nucleus/0012Nuc/wolfgang_dobereiner.htm.

An extensive description of Döbereiner's triads theory can be found at www.rod.beavon.clara.net/doberein.htm.

Randall C. Willis *is a senior associate editor of* Today's Chemist at Work. *Send your comments or questions about this article to tcaw@acs.org or to the Editorial Office address on page 6.* ◆

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