The Atom Man

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John Dalton led modern chemistry down the atomic road.

Eminent British chemist John Dalton read his paper, "On the Absorption of Gases by Water and Other Liquids", before the Literary and Philosophical Society of Manchester on October 21, 1803, and firmly established chemistry on its modern footing. Drawing on the work of others, as well as his own research, Dalton crafted a theory of atomism that was at once a bold expression of scientific originality and a cautious summation of much foregoing chemical investigation.

Early Life and Work

Dalton was born in 1766 to a modest Quaker family in Cumberland, England. He received his early education at the hands of his father, a weaver, and at the local Quaker school. Dalton demonstrated an early aptitude for mathematics, and by the age of 12 taught at the same Quaker school. Two years later, he left for another village school, where he remained for more than a decade.

In the spring of 1793, Dalton moved to Manchester, where he spent the rest of his life. In Manchester, he taught mathematics and natural philosophy at the New College, an institution of higher learning established for those who dissented from the teachings of the Church of England and who were accordingly denied entry to Cambridge and Oxford.

A year later, he was admitted to the Literary and Philosophical Society (LPS) of Manchester, under the auspices of which he published his important scientific works. Early in his educational career, Dalton became interested in meteorology and the atmosphere, and in 1787 he began his first scientific project, a diary of meteorological observations that eventually contained more than 200,000 entries. In 1794 he published some of these observations as *Meteorological Observations and Essays*. The book contains the rudiments of his later theories, but was little appreciated by the reading public of the time.

Among his conclusions was the notion that the rotation of the earth and its variations in temperatures were implicated in the generation of the trade winds. George Hadley had proposed just such a theory in 1735, so Dalton's ideas on that score were hardly original. Other meteorological subjects he read before the LPS included measuring devices such as the barometer, thermometer, and hygrometer; and evaporation, atmospheric moisture, and cloud formation.

John Dalton, 1766–1844.

DALTON PORTRAIT: NATIONAL LIBRARY OF MEDICINE

A (Color) Blind Eye

Perhaps because he was color-blind, Dalton investigated the causes of color-blindness. In *Extraordinary Facts Relating to the Vision of Colours* (1794), Dalton gave one of the earliest accounts of the inability of some people to perceive certain colors, and color-blindness came to be called "Daltonism". He postulated that color-blindness was caused by a discoloration of the aqueous humor of the eyes. In fact, he stipulated in his will that his eyes were to be examined after his death in order to ascertain whether or not the fluid of his eyes had been tinted blue. The postmortem showed his eyes to be perfectly normal, but DNA tests in the 1990s conducted on one of his eyes preserved by the Royal Society showed that he lacked the pigment that gives sensitivity to greens, the condition known as deuteranop.

Dalton and Atomism

By 1800, Dalton had become the secretary of the Manchester LPS, and in 1805 he presented a series of papers to the society outlining key points about the behavior of gases in his series of essays, "Experimental Essays on the Constitution of Mixed Gases". He proposed that particles of an elastic fluid or gas were in fact elastic only with particles of their own kind. This extended Boyle's law to mixtures of gases. Dalton's further essay "On the Expansion of Gases by Heat" proposed the law that all elastic fluids expand the same quantity at the same heat. Jacques Charles and Joseph Louis de Guy-Lussac arrived at the same notion almost simultaneously. It is in this work that we see interest in the particles of matter themselves, rather than their behavior, begin to emerge in Dalton's thinking.

While the research had been carried out throughout the early years of the 19th century (Dalton's habit of revising his notes after presentation of ideas to the LPS makes exact dating difficult), in 1808 and 1810 Dalton published a two-volume book, *A New System of Chemical Philosophy*, which changed everything. In the book, he developed the ideas he had been working on since 1801 concerning heat and chemical combination and laid the foundation for systematic chemical notation by graphically representing the arrangements of atoms in compounds. Dalton united atomism with the notion of chemical elements to put chemistry on a strong new footing.

Atomism itself was not a particularly new idea in the early 19th century. The ancient Greek philosopher, Democritus

(460–370 B.C.E.), proposed as part of a materialist philosophy that matter was made of tiny, indivisible pieces. Democritus suggested that there were certain basic elements that could be neither created nor destroyed, but that could be arranged into myriad forms. These atoms possess simple properties only, specifically size, shape, and mass. Anything else that we perceive, such as color, is merely the result of interaction between the particles.

In the 17th century, Isaac Newton hypothesized that matter was made up of atoms—small, hard homogeneous spheres adhering to one another through the gravitational force they exerted. The notion that matter was composed of atoms, and that there existed pure substances made of only one kind of atom (elements), was fairly common during the later Enlightenment period and into the 19th century. As a member of the Manchester LPS, Dalton was certainly familiar with these ideas.

Scientific discovery is rarely linear, and the "right ideas" almost never spring fully formed from the scientist's forehead like Athena. Dalton came at the notion of atomic structure only gradually, at first as a physical concept forced on him by his study of the atmosphere, heat, and gases. Dalton's notebooks and papers were destroyed during the bombing of Manchester during World War II, so historians of science perforce rely on earlier generations for their reporting of Dalton's day-to-day investigations. In his 1802–1804 notebooks, Dalton records on September 6, 1803, a table of the relative weights of the atoms of several substances, including water, carbon dioxide, and ammonia. With his assumption that matter always combines in the simplest possible manner, he used this chemical analysis to arrive at the idea that the gases he observed were made of atoms of differing weights, of different elements.

Extending this idea to matter more generally, Dalton formulated his theory of atomism, which contains four basic parts. The first part is that chemical elements are made of atoms. These atoms are minute, discrete, indestructible particles invisible to the technology of the day. Dalton's idea that an element is a chemical substance that cannot be further reduced to atoms derives from Lavoisier. While Dalton's atoms are frequently imagined as featureless balls, Dalton never ruled out the possibility of subatomic structure. He just couldn't see it or intuit subatomic properties.

The second and third parts of Dalton's theory of chemical atomism holds that the atoms of an element are identical to each other and different from those of other elements. This was Dalton's law of constant composition. It wasn't original to him; one finds it both in the works of Democritus and in chemical texts of Dalton's era. His contribution was that although chemists had long claimed that different elements had different weights, no one had been able to figure out those weights. Dalton was the first to do so.

The fourth part of his theory held that elements combine in small whole-number ratios. The relative number of atoms in a given compound is consistent from sample to sample. This explained Joseph Louis Proust's law of definite proportions (1797). Water, for example, will always consist of two parts hydrogen and one part oxygen, a simple ratio of 2:1. This idea likewise explained Dalton's own law of multiple proportions, derived from his observation that some atoms occur in different proportions with the same elements. For example, carbon and oxygen can produce carbon monoxide and carbon dioxide. The masses of one element combine with a fixed mass of a second element. Thus, the amount of carbon changes but always in relation to the same mass of oxygen.

Criticism and Reception

Dalton's theory was not universally or immediately accepted. One critic wrote, "Atoms are round bits of wood invented by Mr. Dalton." More damagingly, Sir Humphrey Davy, easily the greatest English chemist of the age, described Dalton as a rough experimenter who could usually be counted on to find the results he sought, relying on his head rather than empiricism. Dalton wrote in the preface to the second part of the first volume of his *New System* that he had so often been misled by the results of others that he was determined to trust only what he verified. To others, however, this too often looked like a lack of receptivity to other, perhaps contradictory, ideas. It looked like he was cooking the books.

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Despite such charges, Dalton gradually gained recognition and even honor for his contribution. He was elected a Fellow of the Royal Society in 1822, and eventually a foreign associate of the Paris Academy of Sciences. In 1833, the British government granted him a pension of £150, which was doubled in 1836. In the mid-19th century, this was a lavish sum. But perhaps the greatest honor is this: The units of atomic mass, while now called unified atomic mass units (amus), were once called "daltons".

Further Reading

Biographical history; www.archiveshub.ac.uk/news/jdalton.html.

Dalton, J. On the Absorption of Gases by Water and other Liquids; http://webserver.Lemoyne.edu/faculty/giunta/dalton52.html.

John Dalton; www.wikipedia.org/wiki/John_Dalton.

Park, J. L. John Dalton (1766–1844): The Father of the Chemical Atomic Theory; http://dbhs.wvusd.k12.ca.us/AtomicStructure/Dalton.html.

Plambeck, J. A. Atomic Theory of Matter: John Dalton; www.psigate.ac.uk/newsite/reference/plambeck/chem1/p01021.htm.

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