# Dawn of Science

## 24. Chemistry Comes of Age

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***With the works of Cavendish, Priestley and Lavoisier, chemistry emerged as an exact science.***

Yet another branch of science to come of age in the eighteenth century was chemistry. What helped its growth into an exact science was the preliminary work of Henry Cavendish (1731–1810) and Joseph Priestley (1733–1804) from England and extensive contributions by Antoine Lavoisier (1743–1794) from France.

Cavendish, descendant of two prestigious families of Dukes, had his early education in London followed by four years at Peterhouse College at Cambridge. Though he completed his studies, he never took the final degree for reasons which are quite unclear. After a short tour of the continent, he settled in London in 1755 with his father who was a skilled experimentalist. As an assistant to his father, Cavendish started doing his own experiments and was soon breaking new grounds, particularly in the study of properties of gases and electricity.

When he was around 40, Cavendish inherited a large fortune from a relative and became a millionaire. (This made a contemporary scientist remark that Cavendish was the richest of all the learned men and most learned of all the rich!). But he was an eccentric genius. He dressed shabbily, spoke hesitantly and very little, never appeared in public and could not stand the sight of women. So much so that he communicated with his housekeeper by daily notes and ordered all female domestics to keep out of his sight. He usually wore a crumpled and faded suit and a three-coloured hat. He had disdain for public acclaim though he did accept fellowships of the Royal Society and Institut de France. He rarely

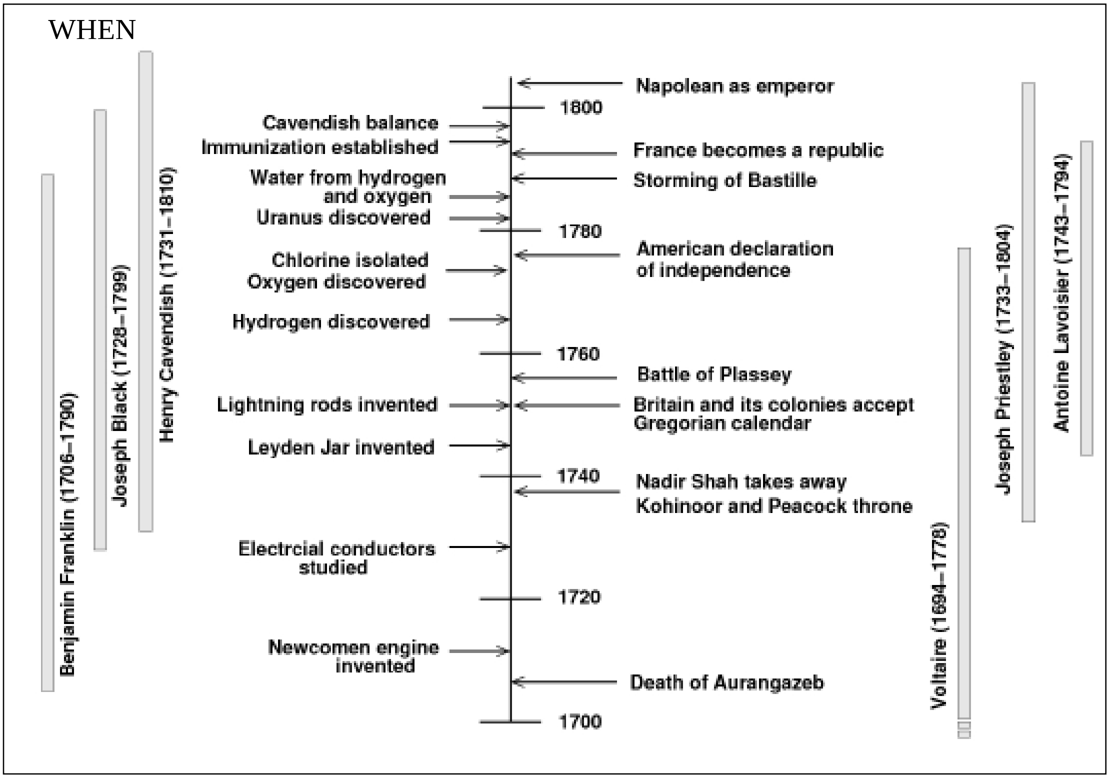


Figure 1.


Figure 2.

published his results and consequently hindered the march of science to a certain extent.

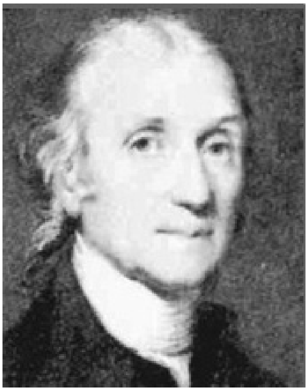

**Figure 3.** Henry Cavendish (1731–1810).
Courtesy: http://www.famousscientists.org/henry-cavendish

In terms of scientific calibre however, Cavendish was excellent. In 1766, he communicated some early results to the Royal Society describing his work on an inflammable gas produced by the action of acids on metals. Though this gas had been noticed before, Cavendish was the first to study its properties systematically. Twenty years later, Lavoisier named this gas hydrogen.

By careful measurement he could determine the density of hydrogen and discover that it was unusually lighter than air. One of the popular ideas in chemistry those days was the hypothetical substance called phlogiston (Greek, 'to set on fire'). All combustible objects were supposed to contain large quantities of phlogiston and the process of combustion was assumed to involve loss of phlogiston. Thus, wood was supposed to contain phlogiston but not ash, which could explain the fact that wood can burn but ash cannot. The remarkable lightness of hydrogen and the fact that it helped combustion made Cavendish conclude (erroneously, of course) that he had isolated phlogiston. It took a few more years for the concept of phlogiston to be laid to rest. Cavendish, however, noticed that when a mixture of hydrogen and air was exploded by means of an electric spark, water was produced. Similar experiments had been performed earlier by Priestley and even James Watt. This result was of crucial significance because it gave the final blow to the medieval idea that water was a pure element; it became clear that water could be formed by a suitable chemical reaction.

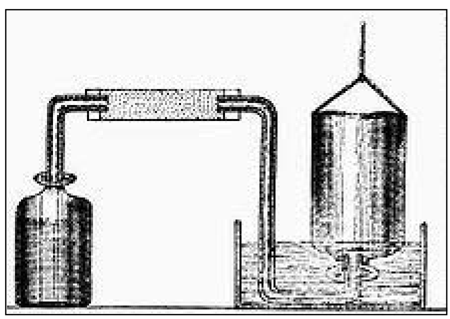

**Figure 4.** Cavendish's apparatus for making and collecting hydrogen.
Courtesy: http://en.wikipedia.org/wiki/Henry_Cavendish

**Box 1. Weighing The Earth**

According to Newton's law of gravitation, two bodies of masses $M$ and m separated by a distance $r$ attract each other with a force given by $F = GMm/r^2$. It follows from this law that the constant $G$ can be computed if the force of attraction between any two bodies can be measured accurately. Once $G$ is known, it would be possible to estimate the mass of the Earth by using the known value of the force by which Earth attracted all bodies.

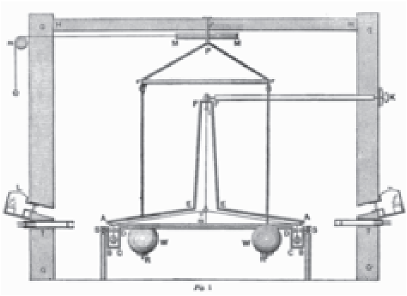

**Figure A.** Cavendish's torsion balance instrument.
Courtesy: http://en.wikipedia.org/wiki/Cavendish_experiment

The difficulty, of course, is that the gravitational force $F$ is extremely tiny at laboratory scales and requires a very sensitive experiment to measure it. One of Cavendish's experiments was to design such an apparatus. His apparatus consisted of a light rod suspended by a wire at the middle. At each end of the rod was a light lead ball. The rod could twist freely about the wire and even a small force applied on the lead balls would make it twist. Cavendish brought two large balls near the light balls, one on either side. By measuring the twist, he could calculate the force of attraction and hence estimate the constant $G$. From the value of $G$, he estimated the mass of the Earth to be 6.6 x $10^{21}$ tons and the density to be about 5.5 g /cubic centimetre. The Cavendish balance has remained a valuable tool in the measurement of small forces.

Cavendish also used electric sparks to make nitrogen combine with air (with the oxygen in air, to use modern terminology) forming an oxide which he dissolved in water to produce nitric acid. He kept adding more air expecting to use up all the nitrogen. However, he noticed that a small bubble of gas, amounting to less than one per cent of the whole, remained uncombined. He speculated that normal air contained a small quantity of very inert gas. We now know that component to be essentially argon. Cavendish also made a significant contribution to the study of electrical phenomena and to the measurement of the gravitational constant (see *Box* 1).

**Figure 4**. Joseph Priestley.
Courtesy: http://en.wikipedia.org/wiki/Joseph_Priestley

Cavendish died in his 78th year. He left his large fortunes to his relatives and virtually nothing to science. This omission was later rectified by the Cavendish family when in 1875 they set up the Cavendish laboratory at Cambridge University which contributed greatly to the development of science in the next century.

Another English chemist who lived during the same period was Joseph Priestley. He was the son of a non-conformist preacher

Priestley used a new technique of collecting the gas over mercury rather than over water which was the practice earlier. In this way, he could collect several gases, which were soluble in water.

and was quite radical in his views on religion and politics. In his early days he studied languages, logic and philosophy and very little of science. He first worked as a teacher in a day school at Cheshire. During this time, he wrote several books dealing with English grammar, education and history. Though he never studied science formally, he was always curious about the several new discoveries occurring around him at the time. From 1765 onwards, he made it a point to spend a month every year in London where he could keep in touch with leading scientists. Influenced significantly by Benjamin Franklin (1706–1790), he decided to write a book, *The History and Present State of Electricity*, which earned him a place among scholars.

Soon Priestley turned from physics to chemistry. His main interest was in the investigation of gases. Only three gases were known at the time – air, carbon dioxide (which was discovered by Black) and hydrogen which Cavendish had just discovered. Priestley went on to isolate and study several more gases such as ammonia and hydrogen chloride. He used a new technique of collecting the gas over mercury rather than over water which was the practice earlier. In this way, he could collect several gases, which were soluble in water.

His major discovery, however, came in 1774. It was known that mercury when heated in air would form a brick-red-coloured ‘calx’ (which we now call mercuric oxide). Priestley found that when calx was heated in a test tube, it turned to mercury again but let out a gas with interesting properties. Combustibles burned brilliantly and more rapidly in this gas, mice were particularly frisky in that atmosphere and he himself felt ‘light and easy’ when he breathed it. Since Priestley believed in the phlogiston theory, he reasoned that the new gas must be particularly poor in phlogiston. He called it ‘dephlogisticated’ air; when Lavoisier heard about the discovery he could immediately recognise it for what it was and named it oxygen. Priestley also noted that plants restored the ‘used up air’ to its original freshness by supplying oxygen.

In 1779, Priestley moved to Birmingham as minister of the New

Meeting Congregation. Being a unitarian by faith, he rejected most of the fundamental doctrines of Christianity, including the Trinity, predestination and the divine inspiration of the *Bible*. In addition, he was a strong supporter and defender of the principles that inspired the French Revolution. This and his publications on these subjects made Priestley extremely unpopular in the local community. And when, on July 14, 1791, the second anniversary of the fall of the Bastille, the supporters of the French Revolution organised a meeting in Birmingham, the general public was not sympathetic, and decided to teach those gathered a lesson. In the mob violence that followed, Priestley's house, laboratory and library were burnt down. Priestley managed to escape to London where he taught in a college.


**Figure 5.** Priestley Medal.
Courtesy: http://en.wikipedia.org/wiki/Joseph_Priestley

However, the progress of the French Revolution, the execution of Louis XVI in France, and the declaration of war between France and Britain made life even more difficult for him. In 1794, he left Britain forever and migrated to the United States where he spent his last ten years. He was probably the first scientist to go to the USA to escape local persecution and certainly not the last.

To commemorate Priestley's scientific achievements, the American Chemical Society named its highest honor the Priestley Medal in 1922.

During one of his experiments, Priestley dissolved carbon dioxide in water and found that the solution tasted pleasant and refreshing. Though he didn't make a commercial success of it, he probably deserves to be called the father of the soft drink industry.

## Suggested Reading


[1] **Joy Hakim, *The Story of Science – Newton at the center*, Smithsonian Books, 2005.**

[2] **Isaac Asimov, *Asimov's Biographical Encyclopedia of Science and Technology*, Doubleday, 1982.**



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