Feature Series

Some unremembered chemists

A series of articles that explores the lives and work of selected chemists who have made a significant contribution to the advancement of the discipline, the profession and well-being of mankind, yet who are little remembered.

William Henry, MD, FRS (1774-1836)

Brian Halton

School of Chemical & Physical Sciences, Victoria University, PO Box 600, Wellington 6140 (email: *brian.halton@vuw.ac.nz*)

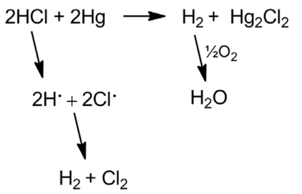
William Henry by James Lonsdale (© National Portrait Gallery, London, with permission)

William Henry was born on December 12 in 1774 at 19 St. Ann's Square, Manchester. He was the third son of Thomas Henry and his wife Mary (née, Kinsey).[1-3] The Henry family hold the distinction of having three generations of chemists, Thomas (1773),[1] William (1809)[4] and William's son (William) Charles (1834),[5] holding Fellowships of the Royal Society continuously for close on one hundred and twenty years from 1773.[5]

Henry senior (1734-1816) was a surgeon and apothecary (a trading chemist) who taught himself chemistry from the traditional eighteenth century text *Elementa Chemiae* written in 1732 by Dutch chemist Boerhaave. Although a surgeon, Thomas Henry was not an MD as, in those days, the majority of surgeons qualified by apprenticeship through an apothecary. However, it was Thomas Henry's chemical acumen that placed him among the more affluent members of Lancashire society. This came from the manufacture of magnesia – magnesium oxide – for which he devised an industrial process and gained the name *Magnesia Henry*. Although little is known about the education of his elder sons, Thomas and Peter, William was privately educated by the Rev. Ralph Harrison who taught Latin and Greek at the nearby Unitarian Cross Creek Chapel, the Dissenters' Meeting House. When the Manchester Academy (which Thomas Henry had helped establish) opened in 1786, Harrison was appointed Professor of Classical Literature[3,4] and William, although only eleven years old and below entry age, was permitted to follow his tutor there. The academy was run by English Presbyterians as one of several dissenting academies that provided religious nonconformists with higher education – the English Universities of Oxford and Cambridge took only Anglicans. As a young boy, William suffered serious injury when a heavy beam fell on his right side. The consequential acute neurological pain he suffered remained with him throughout his life and turned him to study since normal physical boyhood activity was limited. In 1790, at the age of sixteen, he left the academy to become secretary-companion to Thomas Percival, a colleague of his father and the leading physician in Manchester, perhaps best known for crafting the first modern code of medical ethics published in 1794. Percival had poor eyesight and suffered violent headaches, and William's job was to read aloud to him, keeping him familiar with developments in medicine and science, and then taking whatever dictation was required. Thus, William Henry became familiar with Percival's correspondence with the noted men of science and literature of the day. During his time with him, William began to study medicine and he entered Edinburgh University for a medical degree in the winter of 1795.

Edinburgh was the centre of modern medical education in the UK as Oxford and Cambridge held strong to classical medical tradition. While there, the young Henry attended lectures in chemistry given by Joseph Black (1728-1799) who, though old and frail, was still the Professor of Chemistry.[4] He became more drawn to science than medicine and he performed his first piece of serious scientific research there – studies of carbonated hydrogen gas. This was read to the Royal Society by his father on June 29, 1797.[6] After a year of medical school, Henry senior recalled William to Manchester to help run the family businesses as his elder brothers had little appetite for business and lacked the aptitude to assist. William became central to the family affairs,[1,5] and after a short time, he was taken into partnership by his father. He ran the magnesia factory, the mainstay of the family fortune, under the name T & W Henry from 1797. It survived under this name until the end of 1933. Late in 1805, William returned to Edinburgh to complete his studies, leaving the factory in the hands of a manager. His two years there gave him his only period freed from commercial responsibilities and he graduated MD with a thesis on uric acid (*De acido urico et morbis a nimia ejus secretion ortis*), a substance that continued to hold his interest.

William Henry had a natural talent for experimental study and it was over the ten years following his first return from Edinburgh that he made his major contributions to chemistry, carrying the skills he learned as a manufacturing chemist to the research bench. Apart from magnesia, the other major activity of the Henrys was the production of aerated waters – soda water with or without added flavouring. Thus, William Henry had a life-long interest in gases, their essential properties and their chemical behaviour, and, later, he became actively involved in the gas lighting industry in Great Britain. His interest in gases led him to work with his father on pneumatic medicine - the inhalation of gases to treat disease and especially consumption - at the Royal Manchester Infirmary and it directed much of his early work. In this, William studied the composition and decomposition of muriatic acid gas (HCl) which, like all acids at that time, was thought to contain oxygen. He came close to solving the problem of its composition in 1800, some ten years ahead of Humphrey Davy. His results appeared in the *Philosophical Transactions* of the Royal Society in 1800.[7] Henry repeatedly exposed HCl to electric discharges and when performed over mercury he saw a volume reduction and the formation of a white solid [now recognised as mercury(I) chloride].

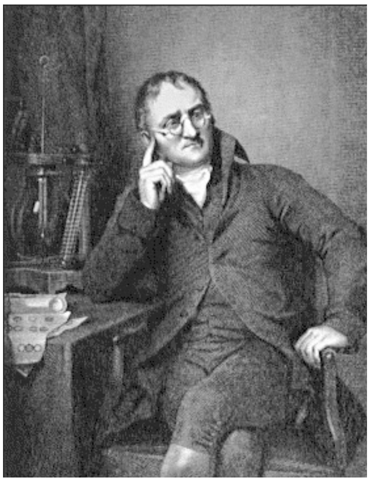


Scheme 1. Electric discharge of hydrogen chloride

When repeated with HCl in the presence of O_2, a greater volume drop was seen as water is formed from reaction of the liberated hydrogen with the oxygen, and in the absence of mercury, chlorine was produced (Scheme 1). When Davy finally showed that muriatic acid was comprised of hydrogen and chlorine only, Henry supported him and provided additional evidence in 1812.[8] Although Henry was unable to come to the correct conclusion regarding HCl until after Davy's paper, it is clear that his results are correct and of significance. However, the work for which he is best known is on the solubility of gases.

Henry's studies on gas solubility gave rise to what we now regard as Henry's law. It also led to a friendship and collaboration with the teacher John Dalton, most notably from 1800-1805.[9] He helped the colour-blind Dalton with his experiments and, while Dalton subsequently became world-famous for his theories, his practical abilities were less enduring. Thus, Dalton and Henry shared an interest in the chemistry of gases and liquids. Understandably, William Henry approached his study of them from the viewpoint of an industrialist who manufactured soda water and hoped to use gases in medicine. Dalton, on the other hand, came to chemistry from a metrological background.

By about 1800 Dalton saw the atmosphere as comprising four types of particle – the atoms of oxygen and nitrogen and the compound atoms of water and carbonic acid (carbon dioxide) that were motionless. He could not understand why a puddle of water could diffuse into the atmosphere or why the air did not separate into layers. His discussions with Henry as to what might cause these effects were probably important in the development of his atomic theory. In 1801 Dalton formulated the concept that there was a repulsive force between particles of the same kind in a gas,[10,11] viz. like repels like, and that this resulted in every particle of water in air getting as far from another as possible so that the whole would be evenly distributed throughout the available space. William Henry, initially



John Dalton (1766 – 1844) (from *http://www.wpclipart.com/famous/science/science_2/John_Dalton.png.html*)

opposed to this, converted to acceptance by 1804 saying every gas is a vacuum to every other gas.[12] The change stemmed from his and Dalton's experiments on gas solubility, notable over 1801 and 1802 when both worked on the solubility of gases in water. Because most previous study had been with carbonic acid (carbon dioxide), Henry chose this as his first target and he reported his results to the Royal Society (London) just before Christmas in 1802 and published them in the *Philosophical Transactions* early in 1803.[13] Dalton read his studies to the Manchester Literary and Philosophical Society some ten months later, on October 23, 1803, and published them in the Memoirs of the Literary and Philosophical Society of Manchester in 1805.[14] Henry's conclusion, which appears in an appendix to the original paper,[13] became known as Henry's law and for this he was awarded the Copley Medal in 1808. The law, one of the fundamental gas laws, states:

> *At a constant temperature, the amount of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.*

An equivalent is:

> *The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid.*

Not surprisingly, the most common practical illustration of Henry's law is provided by carbonated soft drinks. Before the container of carbonated drink is opened, the gas above the drink is almost pure carbon dioxide at a pressure slightly higher than atmospheric. The drink itself contains dissolved carbon dioxide. When the bottle or can is opened, some of this gas escapes, giving the characteristic hiss (*pop* in the case of sparkling wines). Because the partial pressure of carbon dioxide above the liquid is now lower, some of the dissolved carbon dioxide comes out of solution as bubbles. Obviously, when a glass of the drink is left in the open, the concentration of carbon dioxide in solution equilibrates with the carbon dioxide in the air, and the drink goes flat. A more complex example of Henry's law is in the bends that can be suffered by underwater divers.

Dalton's experiments on the solubility of gases provided a mechanical model of it and led to his conclusion that the differences in the solubility of different gasses depended on the weight and number of the ultimate particles of the several gases,[13] a generalisation that is now known as Dalton's law of partial pressures.[14] Henry was much more concerned with the facts associated with his studies than with theory, but when they fitted to a theory he was delighted. Thus, Henry began his study from the knowledge that the solubility of CO_2 in water was increased with increased pressure. However, in 1801, the preparation and handling of pure gases was essentially unknown and his work used gas mixtures – almost always containing amounts of air. This led to the overlap of his and Dalton's studies and Henry's 1802 presentation on the quantity of gases absorbed by water was possible only after taking into consideration the mixed gases and Dalton's law of partial pressures known to him but unpublished at that time. The nature of the experiments and the rather crude equipment then available has been nicely described by the Farrars and Scott[9] and does not justify further discussion here. Suffice to say that the true solubility of CO_2 could only be determined from an analysis of the undissolved gas and applying the law of partial pressures to it. This only became apparent to Henry after he had read his paper and presented his manuscript for publication. It was clarified in the appendix where he says that the absorption of gases by water is a purely mechanical effect and that the amount is exactly proportional to the density of the gas, independent of any other gas with which it may be mixed. The result of some 50 experiments on CO_2, H_2S, N_2O, O_2 and N_2 led to the formulation of Henry's law.

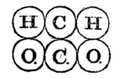
William Henry's subsequent work with gases included the electrolysis of ammonia in order to assist in determining its composition.[1] Here, a series of experiments led to the conclusion that dry ammonia doubled in volume (1 volume increased to 1.98 volumes) from electric discharge. We now know that two volumes of N_2 are replaced by four volumes of gas as per:

$$2NH_3 \rightarrow N_2 + 3H_2$$

However, it is his studies on the destructive distillation of coal and oil that led to his involvement with the gas lighting industry and it provided the only fundamental research in that industry until the mid-1800s.[15] His papers on this were published over the 1805-1821 period.[16-20]

It was towards the end of the 18^{th} century that the gaseous products from coal were beginning to receive attention. William Henry analysed the constituents of the gases produced and distinguished between some of them by chemical methods, and he studied their suitability for lighting. Thus, he showed that the gas mixtures comprised carbonic acid (CO), carburetted hydrogen (CH_4), hydrogen, olefiant gas ($CH_2=CH_2$) together with some carbonic acid gas (CO_2) and sulfureted hydrogen (H_2S). He was in disagreement with other authors of the day in that he correctly showed the composition of the gases from coals, oils and other organic substances such as wood and peat. They comprised mixtures of a few simple compounds, predominantly hydrogen, methane and the oxides of carbon. Henry's last important paper on hydrocarbons[20] contained speculation on the way methane is formed "in natural operations". Although we know that water and charcoal yield hydrogen and the oxides of carbon (water gas), and that the formation of methane in stagnant pools is a microbial process, Henry's speculation provides one of the very early attempts to give a mechanism in terms of the atomic theory. One needs to remember that water was thought to be 'OH' and methane (carburetted hydrogen) 'CH_2' in reading that section of the original paper which appears below.[20] Not only does he account for the products as he saw them, he also proposes a metathetical way in which the 'OH' and 'C' approach and separate, a concept some 150 years ahead of olefin metathesis.

> The process, by which carburetted hydrogen gas is evolved in natural operations, is no doubt the decomposition of water, and admits of being explained on the atomic theory of Mr. DALTON, by supposing two atoms of charcoal to act at once on two atoms of water. One atom of charcoal attracts the two atoms of hydrogen, forming carburetted hydrogen gas, and the other atom of charcoal unites with two atoms of oxygen, constituting carbonic acid. This is illustrated by the annexed figure, in which two atoms of charcoal C.C. are represented as interposed between two atoms of water, each consisting of an atom of hydrogen and an atom of oxygen. Dividing the diagram vertically into three parts, we have the original substances; and separating it horizontally, we obtain the two new compounds. This theoretical view of the subject is confirmed by the fact, that the carburetted hydrogen, formed at the bottom of stagnant pools, is never accompanied by carbonic oxide, but always by carbonic acid, the full quantity of which is prevented from appearing, in consequence of the absorption of a great part of it by the mass of water, under which the changes are taking place.



Beyond these insights, it was a result of William Henry's 1808 paper[17] that ethylene became easily identifiable. He showed that it forms an oily liquid (1,2-dichlorethane) on mixing with chlorine and it was from this and the 1795 work of Dutch chemists (Deimann, van Troostwyck, Lauwerenburgh and Bondt) that it became known as *olefiant gas*. This organic reaction was also well ahead of the understanding of halogen addition to multiple carbon-carbon bonds and some 20 years before Wohler's urea synthesis.

Henry's involvement with the gas lighting industry included experiments which showed that sulfureted hydrogen (H_2S) was the main contaminant of raw coal gas and that the best coals for illumination purposes unfortunately gave the greatest quantity of H_2S.[15] He suggested that the most effective way of removing the contaminant would be by agitation with quicklime and water. Thus, raw coal gas could be used for lighting only in well ventilated areas unless the hydrogen sulfide was removed. Samuel Clegg tried to put this into practise in a mill in Coventry in 1809 but it was unsuccessful because of the short time that the gas and lime were in contact. It seems that Clegg and Henry then collaborated in the installation of gas lighting at Stonyhurst College, the Jesuit College in Lancashire. This was the first non-industrial building to be so illuminated. For this they constructed a vessel containing lime-water through which the raw gas was bubbled prior to passing to the gas holder. Henry showed that the purified gas was perfectly free of the contaminant and the installation was a complete success. Lime was then used as a "sweetener" for the gas over the next fifty years.[15]

William Henry's reputation was significant and he was invited to let his name be advanced for the inaugural Regius Chair in Chemistry at Glasgow University. He declined on the grounds of his family business, his health, and his growing family; he had nine children of whom six lived to maturity. The position went to Henry's friend from Edinburgh days, Thomas Thomson, who held it from 1818 until his death. William became a man of considerable wealth with homes to match. By the late 1820s his health was deteriorating and he took no further part in experimental chemistry, becoming an elder statesman whose opinions and views were sought and valued by many. He was elected a Fellow of the Royal Society in February 1809, having been awarded their prestigious Copley Medal in 1808. He held the position of Vice-Chairman of both the Literary and Philosophical Society and the Natural History Society of Manchester and was one of the founding members and life member of the British Association for the Advancement of Science. His 1799 textbook *An Epitome of Chemistry: In Three Parts* was renamed *Elements of Experimental Chemistry* and enjoyed considerable success, going through eleven editions over some 30 years.[21]

After the marriage of his son Charles in 1834, William and the rest of his family moved to Pendlebury, some four miles out of Manchester. He died there some two years later on September 2, 1836. His neurological pains had increased to the extent that during the night he went to his private chapel and ended his life with a bullet through the mouth. His son, William Charles (who had qualified in medicine at Edinburgh in 1827, was an Honorary Physician at the Manchester Infirmary from 1828 and elected FRS in 1834), like his father before him, had been assisting with the magnesia factory and the family business increasingly as his father's health deteriorated. After his father's death he took over the company keeping the name and running it until his own death in 1892. However, after his father's death he retreated more and more from active participation, taking up the life of a country gentleman at Hatfield near Ledbury in Herefordshire. He also withdrew from practical science but kept many scientific friendships, notably one with Liebig who he had met in Germany and hosted on his first visit to Britain in 1837.

References & Notes

1. Craig Thornber, Cheshire, UK; see http://www.thornber.net/cheshire/ideasmen/henry.html (accessed 22 Nov 2013).
2. Henry, W.C., A Biographical Account of the late Dr. Henry, F. Looney, Oak St., Manchester, 1837 held in The Portico Library, 57 Mosley Street , Manchester, UK M2 3HY (Ref. Fo18).
3. Farrar, W.V.; Farrar, K.R.; Scott, E.L. *The Henrys of Manchester, Pt.1, Ambix,* **1973**, *20*, 183-208.
4. Farrar, W.V.; Farrar, K.R.; Scott, E.L. *The Henrys of Manchester, Pt.6, Ambix,* **1977**, *24*, 1-26.
5. Farrar, W.V.; Farrar, K.R.; Scott, E.L. *The Henrys of Manchester, Pt.2, Ambix,* **1975**, *22*, 179-207.
6. Henry, W. *Experiments on Carbonated Hydrogenous Gas; With a View to Determine Whether Carbon be a Simple or a Compound Substance*, *Phil. Trans. Royal Soc. Lond.* **1797**, *87*, 401-415; see: http://rstl.royalsocietypublishing.org/content/87/401.full.pdf (accessed 25 Nov 2013).
7. Henry, W. *Experiments for decomposing the muriatic acid*, *Phil. Trans. Royal Soc. Lond*. **1800**, *90*, 188-203; see: http://rstl.royalsocietypublishing.org/content/90/188.full.pdf (accessed 27 Jan 2014).
8. Henry, W. *Additional Experiments on the Muriatic and Oxymuriatic Acids*, *Phil. Trans. Royal Soc. Lond*. **1812**, *102*, 238-246; see: http://rstl.royalsocietypublishing.org/content/102/238.full.pdf (accessed 27 Jan 2014).
9. Farrar, W.V.; Farrar, K.R.; Scott, E.L. *The Henrys of Manchester, Pt.3, Ambix,* **1974**, *21*, 208-228.
10. Dalton, J. *Nicholson's J.*, **1801**, *5*, 241-244; *Man. Mem*. **1802**, *5*, 535-606.
11. The *Journal of Natural Philosophy, Chemistry, and the Arts* was generally known as *Nicholson's Journal,* an early scientific journal begun in 1797 in Great Britain by William Nicholson, the sole editor; *Memoirs of the Literary and Philosophical Society of Manchester* is abbreviated to *Man. Mem.*
12. Henry, W. *Nicholson's J.*, **1804**, *8*, 297-301; *Phil. Mag*. **1804**, *19*, 193-196.
13. Henry, W. *Experiments on the quantity of gases absorbed by water, at different temperatures, and under different pressures*, *Phil. Trans. Royal Soc. Lond.* **1803**, *93*, 29-43 with appendix p. 274-276; see http://rstl.royalsocietypublishing.org/content/93/29.full.pdf+html?sid=0d5a0bac-de4e-4c34-a785-62e88294b999 (accessed 27 Nov 2013).
14. Dalton, J. *Man. Mem*. **1805**, *1*(2nd series), 271-287.
15. Farrar, W.V.; Farrar, K.R.; Scott, E.L. *The Henrys of Manchester, Pt.4, Ambix,* **1975**, *22*, 186-204
16. Henry, W. *Nicholson's J.*, **1805**, *11*, 65-74.
17. Henry, W. *Nicholson's J.*, **1808**, *19*, 149-153.
18. Henry, W. *Phil. Trans. Royal Soc. Lond*. **1808**, *98*, 282-303 (see: http://rstl.royalsocietypublishing.org/content/98/282.full.pdf; accessed 29 Jan 2014).
19. Henry, W. *Man. Mem.* **1819**, *3, 391-429*
20. Henry, W. *Phil. Trans. Royal Soc. Lond*. **1821**, *111*, 136-161 (see: http://rstl.royalsocietypublishing.org/content/111/136.full.pdf; (accessed 29 Jan 2014).
21. Henry, W., *An Epitome of Chemistry: In Three Parts*, J. Johnson, London, 1799. Henry, W. *Elements of Experimental Chemistry*, 11th edn., Baldwin & Cradock, London 1829, pp. 770.