From Books to Batteries

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The laws governing electrolysis developed by Michael Faraday, who originally trained as a bookbinder, led to the determination of the Faraday constant, as Daren Caruana recounts.

Faraday's first foray into experimentation with electricity happened at a rather unexpected place — at the back of a bookbinders and bookseller in Blandford Street in London. In 1804, at the age of fourteen, he worked there, initially as an errand boy. When the bookshop owner recognized Faraday's intellect, he trained him as a bookbinder, quickly acquiring skills that certainly prepared him well for experimental science. But more importantly, Faraday was reading and binding the leading scientific texts of the time. After an article on electricity in the Encyclopaedia Britannica captured his interest, he started building electrical instruments at the back of the booksellers. With batteries he had constructed out of copper, felt discs and the newly available metal zinc, he decomposed solutions of magnesium sulphate, copper sulphate and lead acetate. [1]

His time as a bookbinder's apprentice instilled an insatiable appetite for precision and rigour in Faraday that was further fostered by Sir Humphry Davy's tutelage at the Royal Institution. This lead Faraday to investigate electricity more seriously. Between 1832 and 1833, he discovered the laws of electrolysis. This was when he recognized that the amount of electricity needed to release one gram equivalent of any element from its solution, was constant — this number later became known as the Faraday constant. Affectionately referred to as "among the most accurate generalisations in science" [2]. Faraday's insights were remarkable at a time when many chemical elements and also the electron were yet to be discovered.

The work Faraday carried out at the Royal Institution laid the foundations of the field of electrochemistry. The Faraday constant with its value around 96485 C mol^{-1} is at the heart of electrochemistry, as it connects electricity, charge and matter.

The modern electrochemistry nomenclature of electrode, electrolyte, electrolysis, anode, cathode, ion, anion and cation also credited to Faraday. As the depth of his understanding increased, he began to lack the appropriate scientific terminology to describe his ideas and findings. In February 1831, he sought the assistance of Reverend William Whewell F.R.S. at Trinity College, Cambridge — an established Anglican clergyman, philosopher and accomplished scientist. Faraday first proposed 'eastode' and 'westode' for the terminals of a battery. Whewell, however, was unimpressed with these suggestions and countered with 'anode' and 'cathode' coming from the Greek words anodos and cathodos meaning 'asent' and 'descent' respectively.

All electrochemical cells are composed of an anode, a cathode and an electrolyte. Rechargeable batteries — essential for modern life — are elegant electrolysis cells when being charged. Although referred to as storage devices, they do not physically store charge but rather the chemical energy required to push electrons through an electronic circuit. The Faraday constant provides the physical limit of the total charge that can be driven through an external circuit.

In September 1832, Faraday wrote to Hans Christian Ørsted, the Danish pioneer in magnetism, about the progress of his experiments, “I do not know where they may conduct me but I hope and believe they will ultimately prove of some interest” [1]. In fact, his careful deduction of the laws of electrolysis underpin the world’s electronics industry to this day. The power of electrolysis is the ability to drive thermodynamically expensive redox reactions. In theory, if it is possible to apply a high (or low) enough potential difference, one can drive any redox reaction. In practice, the limiting factor in electrolysis is the electrolyte itself: the oxidation and reduction of the liquid electrolyte defines the potential window, within which redox reactions can be investigated. Recent work substituting the liquid electrolyte for an ionized gaseous medium such as plasma could overcome this limitation [3]. The absence of any liquid in the electrolyte opens the possibility to access redox chemistry beyond any solvent limits. This could enable the reduction of carbon dioxide to elemental carbon at a simple electrode with technologically useful rates, could be a game changer in the carbon economy.

Faraday viewed scientific discovery as a great leveller. In his eyes science did not discriminate on the basis of education or social and political standing. He was a strong believer that science was for the benefit of all. Consequently, he felt it his duty to communicate his latest discoveries to the public in lectures, and so he initiated the Christmas Lectures at the Royal Institution in 1825. Faraday’s legacy and his imprint on modern day physics and chemistry is rightfully still felt and appreciated — certainly not bad for a bookbinder born in Elephant and Castle in South London!

References:

[1] James Hamilton, “Faraday, the life”, HarperCollins, 2002
[2] John Meurig Thomas, “Michael Faraday and the Royal Institution: The Genius of Man and Place”, Taylor & Francis, 1991.
[3] Maria Calleja, Atif Elahi & Daren J. Caruana, *Communications Chemistry* **1**, 48 (2018).