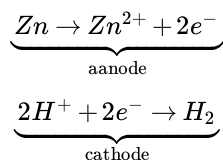# 10.1: Electricity

Electricity has been known for some time. Ancient Egyptians, for example, referred to electric fish in the Nile River as early as 2750 BC (Moller & Kramer, 1991). In 1600, William Gilbert studied what would later be seen to be electrostatic attraction, by creating static charges rubbing amber (Stewart, 2001). And Benjamin Franklin's famous experiment (although it is actually uncertain if he performed the experiment) of attaching a metal key to a kite string occurred in 1752, and showed that lightening is an electrical phenomenon (Uman, 1987).

One of the biggest breakthroughs in the study of electricity as a chemical phenomenon was made by Alessandro Volta, who in 1799 showed that electricity could be generated by stacking copper and zinc disks submerged in sulfuric acid (Routledge, 1881). The reactions that Volta produced in his **voltaic pile** included both **oxidation** and **reduction** processes that could be considered as **half-reactions**. The half-reactions can be classified as **oxidation** (the loss of electrons) which happens at the **anode** and **reduction** (the gain of electrons) which occurs at the **cathode**. Those half reactions were

$$\underbrace{Zn \rightarrow Zn^{2+} + 2e^-}_{\text{aanode}}$$

$$\underbrace{2H^+ + 2e^- \rightarrow H_2}_{\text{cathode}}$$

The propensity of zinc to oxidize coupled with that of hydrogen to reduce creates a potential energy difference between the electrodes at which these processes occur. And like any potential energy difference, it can create a force which can be used to do work. In this case, the work is that of pushing electrons through a circuit. The work of such a process can be calculated by integrating

$$dw_e - -E\,dQ$$

where E is the potential energy difference, and dQ is an infinitesimal amount of charge carried through the circuit. The infinitesimal amount of charge carried through the circuit can be expressed as

$$dQ = e\,dN$$

where e is the charge carried on one electron ($1.6 \times 10^{-19} C$) and dN is the infinitesimal change in the number of electrons. Thus, if the potential energy difference is constant

$$w_e = -e\,E \int_o^N dN = -N\,e\,E$$

But since the number of electrons carried through a circuit is an enormous number, it would be far more convenient to express this in terms of the number of moles of electrons carried through the circuit. Noting that the number of moles (n) is given by

$$n = \frac{N}{N_A}$$

and that the charge carried by one mole of electrons is given by

$$F = N_A e = 96484\,C$$

where F is **Faraday's constant** and has the magnitude of one Faraday (or the total charge carried by one mole of electrons.) The Faraday is named after Michael Faraday (1791-1867) (Doc, 2014), a British physicist who is credited with inventing the electric motor, among other accomplishments.

Putting the pieces together, the total electrical work accomplished by pushing n moles of electrons through a circuit with a potential difference E, is

$$w_e = -nFE$$