Figure 1 - Volta's pile.

Potential with a difference

Chemistry is, by and large, the study of processes that involve the movement of electrons between atoms (or between energy levels in the same atom). It is possible, of course, for electrons to move in other ways. Most commonly, electrons can flow along wires in the form of an electric current.

Electrochemistry is the study of chemical processes that cause electrons to move. This movement of electrons can be generated by movements of electrons from one element to another in a reaction known as an oxidation-reduction ("redox") reaction.

It all began with Italian physician and anatomist Luigi Galvani who marked the birth of electrochemistry by establishing a link between muscular contractions and electricity in 1791 when he proposed a "nerveo-electrical substance" in life forms as a result of observing the twitching legs of a frog he was dissecting.

Alessandro Volta, professor of physics at the University of Pavia, was not convinced by Galvani's explanation of his observations. He suggestead instead that the contact of dissimilar metals was the true source of the stimulation and referred to the electricity so generated as "metallic electricity" and decided that the muscle, by contracting when touched by metal, resembled the action of an electroscope. Furthermore, Volta claimed that if two dissimilar metals in contact with each other also touched a muscle, agitation would also occur and increase with the dissimilarity of the metals.

In 1794 Volta showed that when two metals and brine-soaked cloth or cardboard are arranged in a circuit they produce an electric current. In 1799, he stacked several pairs of alternating copper and zinc discs (the electrodes) separated by cloth or cardboard soaked in brine (the electrolyte) to increase the electrolyte conductivity (see Figure 1). When the top and bottom contacts were connected by a wire, an electric current flowed.

This 'voltaic pile' was the first electrical battery that could provide a continuous electric current to a circuit. It revolutionized chemistry enabling a rapid series of discoveries including: the electrolysis of water into oxygen and hydrogen (1800) and the discovery or isolation of sodium (1807), potassium (1807), calcium (1808), boron (1808), barium (1808), strontium (1808), and magnesium (1808).

The discoveries above were made by using electrolytic cells, where passing an electric current causes a reaction to take place. In this article, we are dealing with Galvanic (or Voltaic) processes. These are defined as chemical reactions that result in the production of electrical energy. These reactions lie at the heart of battery technologies and thus have a vital and ever more important role in modern, mobile electronic devices and in energy storage.

A Galvanic cell is a device consisting of a single pair of electrodes connected via conducting liquids, electrolytes, that converts chemical energy into electrical energy.

In such cells, the electrodes can sometimes use the same electrolyte but more often the process needs to be divided between two containers known as 'half cells', each containing only one of the electrodes, linked with a conductive 'salt bridge' allowing non-metal ions to move between the cells to maintain the charge balance. When the right connections are made, a spontaneous redox reaction takes place which is responsible for the production of electrical energy. A simple schematic is shown in Figure 2.

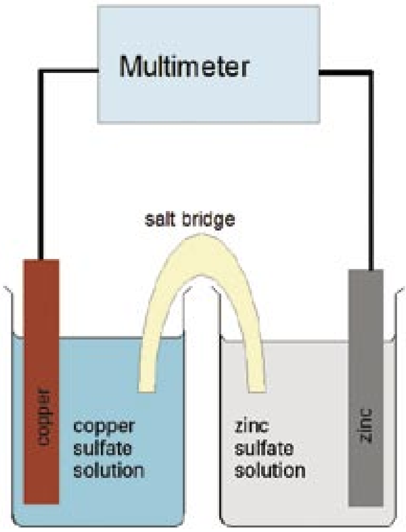

Figure 2 - A circuit of two half-cells.

Where does it fit?

***CfE* Level 2 - 10a**
To begin to understand how batteries work, I can help to build simple chemical cells using readily-available materials which can be used to make an appliance work.

CfE Level 3 - 10a
I can help to design simple chemical cells and use them to investigate the factors which affect the voltage produced.

National 3 - properties of materials
Set up and use a lead-acid cell. Demonstrate that electrical energy can be obtained from a chemical reaction.

National 4 - properties of metals and alloys
Pairs of metals to determine electrochemical series. 'Fruity' batteries using different metal pairs. Simple cells.

National 5 - metals
Make a lead/acid cell to show a rechargable battery. Ion-electron equations can be written for electrochemical cells including those involving non-metals. Combinations of these reactions form redox equations.

In this article, we aim to show how it is possible to make and investigate electrochemistry on a small scale using simple and cheap half cells made from 'tic-tac' boxes. (Pupils can readily be persuaded to eat the contents!). If two are placed side by side (possibly taped together) it is easy to set up simple half cells using only about 15 cm^3 of electrolyte and some small strips of different metals. A simple salt bridge can be made by simply placing a folded piece of filter paper soaked in a salt such as potassium nitrate, between the two half cells. A sample set-up can be seen in Figure 3.

Figure 3- *Tic-tac half-cells.*

Figure 4 *- Simple lead-acid accumulator.*

Using this apparatus (or variations on it) it is possible to carry out a range of investigations:

- The voltages generated can be determined by use of a voltmeter or a suitably set multimeter.
- Current generated can also be determined by using a multimeter or investigated more indirectly by using cells to power devices such as low power solar motors.

It is possible to look at a range of factors that might affect the voltage and/or current generated such as:

- The type of metal.
- The size and shape of the electrodes.
- The type, volume and concentration of the electrolyte.
- The design of the 'salt bridge'.
- Putting cells together in series or parallel.

Beyond that, it is possible to look at some other types of cells such as

Rechargeable lead/acid cells

Using a single tic-tac box (or other container) with two lead electrodes, the cell can be charged with a low voltage dc power source (or battery) and used to drive a solar motor or similar (see Figure 4). The relationship between charging voltage, current or time and the length of time the motor will turn can be the basis of an interesting investigation.

Concentration cells

While these have no commercial importance, they are useful in helping to model how voltages can be generated in biological systems such as nerve cells.

Once again two tic-tac boxes are used to produce two half cells but this time the electrodes are both made of the same metal. The electrolytes in the two half-cells are solutions of the same salt but at very different concentrations. Once again they are joined by a salt bridge (see Figure 5). When the circuit is completed, a small voltage and current is generated. The effect of changing electrodes, electrolytes and concentrations can be investigated as before.

Figure 5 *- A concentration cell.*