Fuel cells for future energy (teacher guide to exercises and experiments)

AIM

- For students to appreciate that electrochemistry is at play in batteries and fuel cells to produce a voltage from chemical energy
- For students to make an electrochemical cell using a potato and zinc, and couple several cells together to light an LED
- For students to electrolyse water to form H₂ and O₂, and then produce a voltage from the alkaline fuel cell

QUESTIONS—answer guide for teachers

1. The zinc in the galvanised nail is acting as the anode, and the copper coin is acting as the cathode. The potato, which is full of water and salts, provides the electrolyte.
2. The pH of the potato will be 5-6. Potatoes contain organic acids.
3. Anode: Zn(s) → Zn²⁺ (aq) + 2 e⁻ (oxidation)
   Cathode: 2e⁻ + 2H⁺(aq) → H₂(g) (reduction)
   Zn(s) + 2H⁺(aq) → Zn²⁺(aq) + H₂(g)
4. The Zn(s) and the H⁺(aq), i.e. the acid within the potato, will be consumed during the redox process; these are acting as the ‘fuel’ for the cell. As these react and run out, the voltage will gradually reduce to zero, as the system reaches equilibrium. These are not easy components to ‘feed in’ to the cell, continuously – this is more like a disposable battery.
5. As you connect up more potato cells in series, the voltage will increase, until eventually you can light the LED. It usually takes 4-6 potato cells to light an LED, albeit dimly!
6. Electrolysis is the reverse process to forming an electrochemical potential; electrical energy supplied by an external source drives a reaction that is NOT spontaneous, and is converted into chemical energy.
7. H₂O → H₂ + ½ O₂. You will produce H₂ gas, at the cathode (attached to the negative pole of the 9 V battery), at twice the rate that you produce O₂, due to the stoichiometry of the reaction.
8. The voltage gradually reduces to zero as the gas fuel reacts and runs out. The H₂ and O₂ are the ‘fuel’ for this cell.
9. The only by-product from this reaction is water; no CO₂ is formed in the fuel cell process.
10. Advantages; the reaction is clean, and doesn’t produce greenhouse or polluting gasses. Water is a plentiful resource, which can be used to form the hydrogen in the first place. Fuel cells are not disposable, like many batteries. Fuel cells do not rely on non-renewable fossil fuels. Disadvantages: Hydrogen is explosive and difficult to store safely, and in a small volume. If hydrogen is produced by the electrolysis of water, energy is needed to do this; if this is done using energy produced by burning fossil fuels, it still contributes to greenhouse gas and other pollutant emissions.