Outreach Activity Reports:

RSC Electrochemistry Special Interest Group - Aluminium Air Battery Teaching Project Report

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Objective:

The objective of this project was to review the GCSE and A-level electrochemistry syllabus used at UK secondary schools and develop a new electrochemistry experiment for use in class room experiments. The experiment was designed to be relevant to both syllabus and use practical skills to enable effective communication of key concepts. It was decided that a simple metal air battery experiment would be designed. The battery would be made from household items that are easily accessible and powerful enough to light an LED. Aluminium was identified as a suitable candidate due to its abundance in domestic items such as coke cans and tin foil. The project was given a £3000 in order to sponsor a university Undergraduate Research Opportunity Project (UROP) at Imperial College London in Dr Gregory Offer's Electrochemical Science & Engineering group at Imperial College London. This was used to employ an undergraduate student for 8 weeks and provide supplies in order to optimise the experiment.

Outcomes:

2nd year undergraduate chemistry student Thomas Chen was selected for the project following an interview process in which 10 candidates were interviewed, supervised by PhD students Michael Parkes and Billy Wu. Thomas then reviewed the GCSE an A-level syllabus. A review of the syllabus was carried out and a summary of the topics taught is shown in the following bullet points:

GCSE:

- Electrolysis – Water and Aluminium Oxide
- Half Cell equations
- Electrolytes
- Oxidations states
- Anions and Cations

A-Level:

- Redox reactions
- Oxidation & reduction

- Oxidation states
- Redox equations
- Cell potential
- Electrode potential & half-equations
- Conventional representation of cells
- SHE & standard conditions
- Calculations involving e.m.f
- Energy and feasibility
- Other case studies such as fuel cells

From the review of the syllabus it was decided that a battery experiment would be particularly relevant to the A-level syllabus where many of the key concepts could be communicated. However the experiment could also be relevant to GCSE as battery chemistry is effectively electrolysis in reverse.

Design of the experiment:

Initially a simple rig that used aluminium foil, salty water, paper towel and wire wool in a beaker was designed. The cell was characterised using electrochemical techniques such as Cyclic Voltammetry (CV) and Electrochemical Impedance Spectroscopy (EIS) and gave the summer student a fantastic chance to learn these techniques. The cell generated very poor voltages and power of around 0.8V and 2mW respectively. Cyclic voltammetry showed that the cell was not very stable and suffered from large mass transport losses. This design was improved by using an alkaline solution of NaOH chosen to make the Oxygen Reduction Reaction more thermodynamically favourable. At this point the summer student was introduced to Pourbaix diagrams. A 2M solution of NaOH solution led to enhanced results and an OCV around 1.1V and optimum power of 4.5mW. The system was optimised for pH and it was found that a PH of 12.5 was most favourable. Beyond this pH, corrosion of the aluminium anode material occurs and this leads to degradation of the cell. Salt was then added to the alkaline solution to improve conductivity and this lead to peak powers of around 5mW.

While the beaker based design worked, it was found to produce too little power to light an LED. Furthermore it did not capture the imagination in terms of being able to take house hold items and turn them into a battery. For the next phase of the project we developed a battery based on an aluminium can. Using the salty alkaline electrolyte developed previously we found similar performance. To overcome this we added an oxidizing agent to the electrolyte and found that household bleach is perfect for this as it is alkaline and contains Sodium hypochlorite. Using 2 Al-can batteries in series enabled LEDS of various colours to be powered.

Teaching Package Development:

The experiment was then written up into two teaching packages for GCSE and A-level. The experiment focussed on the development of the electrolyte and asking questions relevant to the syllabus outlined previously. These can be found in the attached teaching packages.

Testing of the Experiment with School Students:
To test the experiment several 16+ high school students and science teacher Mr Rhazaoui were invited to test the experiment to see if it could be performed within the desired lesson time and to assess the key learning outcomes. The experiment was successfully completed on time and the student feedback gave the experiment 4/5 for enjoyability and usefulness, while students rate the experiment at 2/5 for difficulty. This implies the experiment is both useful and straight forward. It was also found the experiment is best performed in groups of 2.

Presentation at the RSC Electrochem Meeting 2013:
This work was presented by the summer student at the Electrochem 2013 meeting in Southampton where it was well received. This gave the summer student a fantastic opportunity to experience presentations in an academic environment.

Publications:
This work is currently being written up for publication in the Journal of Chemical Education and the RSC, who plan to distribute the work to schools.

Conclusions:
The project ran successfully and a new electrochemistry project has been designed. This will soon be distributed to UK schools through the RSC. In conjunction to this an undergraduate student was given a great chance to learn more about electrochemistry and the key techniques. Thomas then spent another two weeks over the summer developing more complicated metal-air batteries using a fuel cell type rig and more exotic ORR catalysts. These factors meet the key outcomes of the project which were to inspire the next generation of scientists to study electrochemistry.

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Dr. Gregory Offer