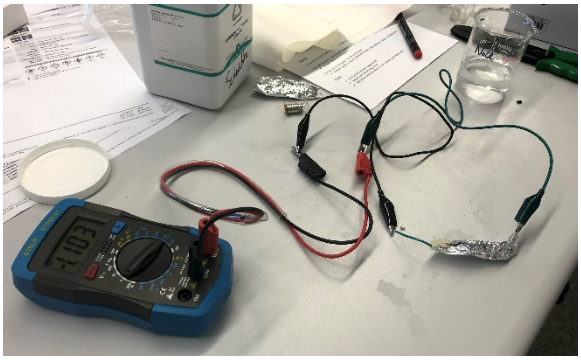
An aluminium-air battery

Description



Students make a working battery out of a piece of aluminium foil, some salt water, a piece of paper towel and some ground charcoal. The voltage can be measured with a voltmeter. Several batteries in a row will light an LED.

Curriculum topics

- Redox reactions
- Energy
- Electrochemistry
- Fuel cells
- Properties of materials (metals, ionic compounds)

Materials

To make one battery

- 5 x 5 cm piece of aluminium foil
- 5 x 5 cm piece of paper towel or filter paper
- 1 tsp (approx. 6-8g) table salt or sodium chloride
- 50 mL of water in a beaker
- 1 tsp (approx. 5 g) activated charcoal, relatively finely ground
- 10 cm long piece of wire with sheath, ends stripped approx. 1 cm exposed metal
- Voltmeter or multimeter with alligator clips and connecting wires
- Optional: red LED

Safety

There are no hazardous materials involved in this experiment. The activated charcoal can form a fine dust and this should not be inhaled.

Waste – the used batteries can be disposed of in the normal rubbish. Don't throw out the stripped wires, as these can be reused.

Procedure

The experiment

1. Lay a 5 x 5 cm piece of aluminium foil on the bench.
2. Dissolve the salt in a beaker with approximately 50 mL water.
3. Wet a ca. 5 x 5 cm piece of paper towel or filter paper with the salt water in the beaker.
4. Spoon the activated charcoal on top of the wet filter paper.
5. Place the wire with one exposed end on to the charcoal and the other sticking out.
6. Fold the aluminium foil around the whole bundle so that the wire stays inside, with one end touching the charcoal and the other end in the air.
7. Connect one terminal of the voltmeter to the exposed wire end and the other to any part of the aluminium foil. Record the voltage measured.

(Optional)

8. Working with other groups, attach a number of batteries in series, and record the change in voltage. With a small LED light, determine how many batteries in series are needed to light the LED.

Teaching notes

Aluminium is a very strong reducing agent and oxygen is a strong oxidising agent. Since the difference in their standard redox potentials is high, the cell delivers a significant voltage.

The chemical equations for the reaction are:

Anode: $Al_{(s)} + 3OH^-_{(aq)} \rightarrow Al(OH)_{3(s)} + 3e^-$ $E^0 = -2.31$ V

Cathode: $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$ $E^0 = +0.40$ V

$$4Al_{(s)} + 3O_{2(g)} + 6H_2O_{(l)} \rightarrow 4Al(OH)_{3(s)}$$

A single cell will not have enough voltage to light an LED, but if you connect four or five in series you should be able to light an LED. There is not enough voltage to light an incandescent (old style) light bulb.

When conducting this activity with younger year-level classes that have not considered redox or electrochemistry, you can focus on the free-moving charged particles through the electric circuit (electrons in the case of the metal foil and wire, ions in the case of the salt solution). This could generate a good discussion about the properties of materials in different physical states.

Aluminium, oxygen and aluminum hydroxide are environmentally friendly and low density, making this a very light battery. However, an aluminium-air battery is not rechargeable.

Students may think that the charcoal has something to do with the chemical reaction and the voltage. To confront this misconception, they can make the battery without the charcoal – this will give almost the same voltage. It can also be left open and will also work.

A challenge for students is to compare this battery with a standard AA battery and see how many aluminium-air batteries are needed to give the same voltage.

References

This activity was modified from an activity generously shared by Diana Kennen (Rockdale K-12) and Matt McDowell (School of Materials Science and Engineering Georgia Institute of Technology).