CLEAN ENERGY INSTITUTE
UNIVERSITY of WASHINGTON

Aluminum air battery activity

This battery uses the oxidation of aluminum at the anode and the reduction of oxygen at the cathode to form a galvanic cell. In the process the aluminum is completely consumed to produce aluminum hydroxide. The metal air battery has a very attractive energy density because part of the reactants come from the air. They have been developed for long range power supplies for electric vehicles. For example rechargeable Li-ion batteries could be used for around town but aluminum air batteries could be used for 1000 mile range. The battery is then replaced and the aluminum hydroxide is re-processed to produce reduced aluminum metal. In a sense the energy for this battery comes from electricity consumed in the aluminum refining process.

The anode oxidation half-reaction is $Al + 3OH^- \rightarrow Al(OH)_3 + 3e^- -2.31\ V.$

The cathode reduction half-reaction is $O_2 + 2H_2O + 4e^- \rightarrow 4OH^- +0.40\ V.$

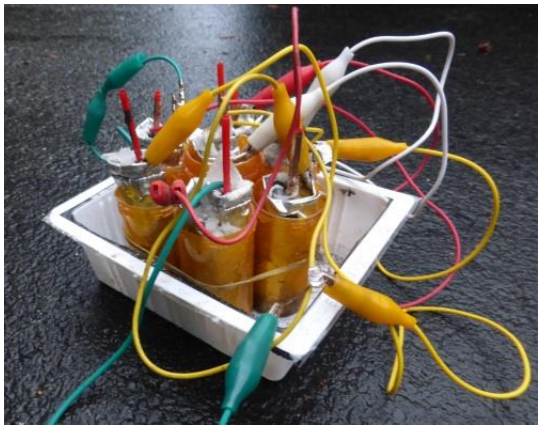
The balanced equation is $4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3 + 2.71\ V.$

(The reaction improves if it is done in a basic solution that supplies excess OH^- ions. With potassium hydroxide electrolyte the 1.2 volts is produced with salt .7 volts per cell. Be very cautious if experimenting with KOH or NaOH electrolytes, use gloves and eye protection)

Grades: 7-12

Time: 1 hour

Materials



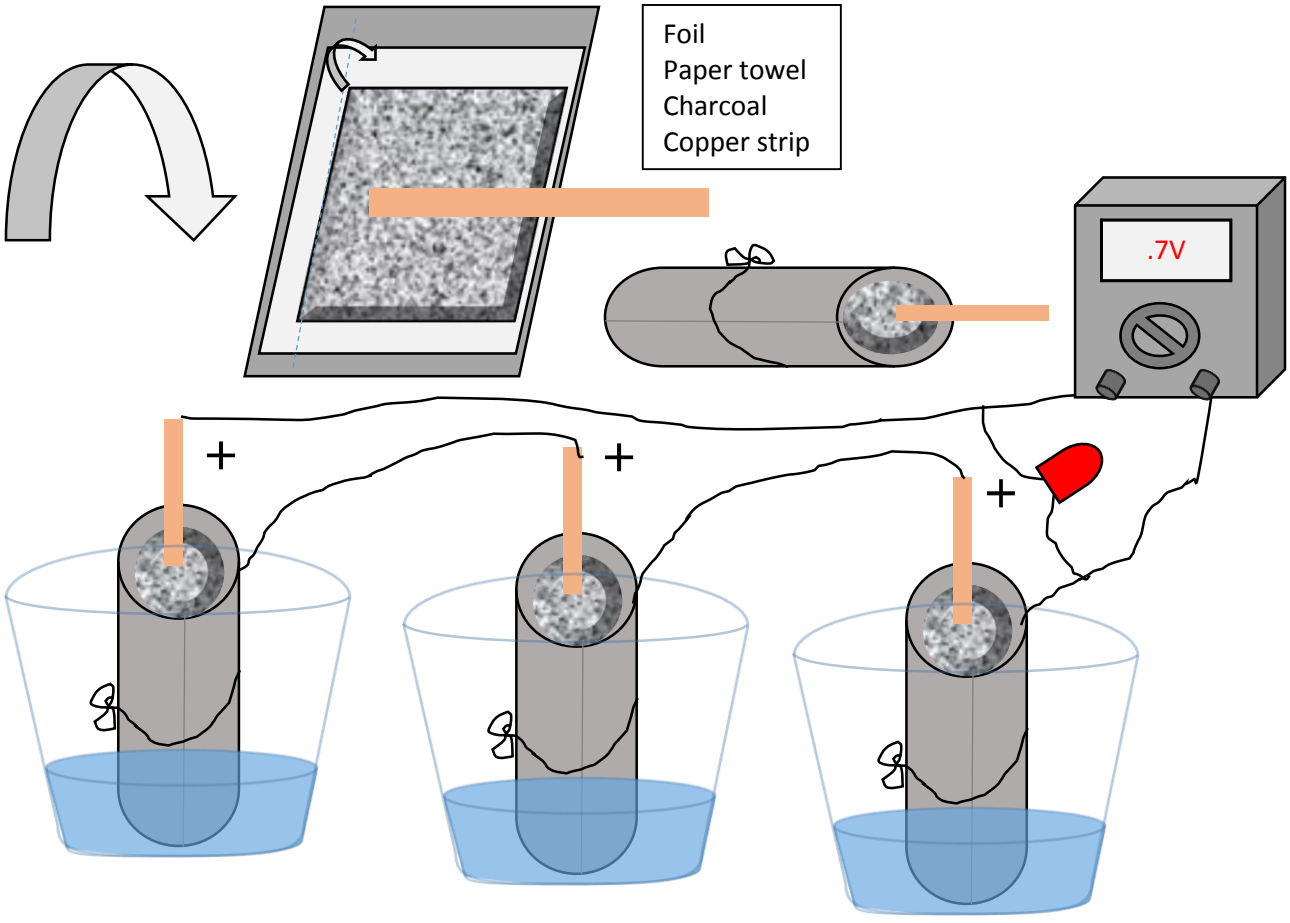
- Aluminum sheet- pie plate or foil
- Paper towel-or water color paper
- Charcoal Briquette or activated charcoal
- Copper foil
- Salt water (saturated) NaCl or MgSO4 (epsom salts), sodium carbonate (washing soda)
- Styrofoam container
- Clip leads

Directions

Cup cell design

This format uses aluminum roll shaped cells that sits in individual cups or pill bottles containing electrolyte reservoirs. The electrolyte wicks up into the charcoal in the center and evaporates slowly and allowing air to penetrate the interior.

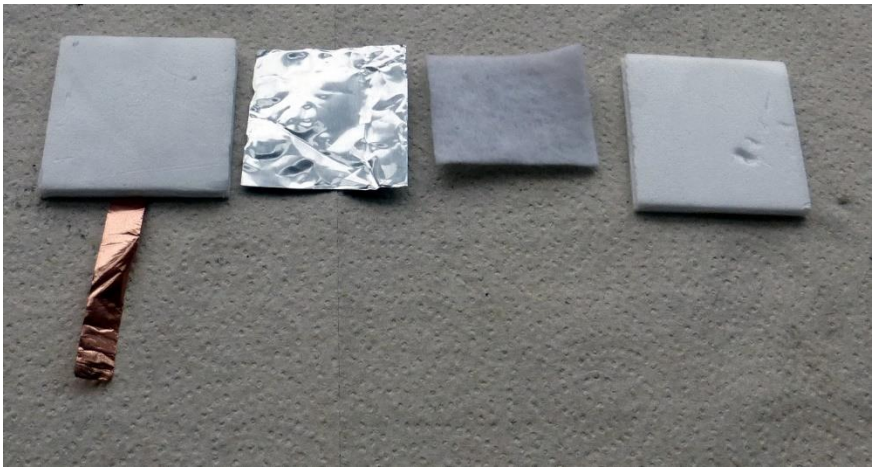
1. Cut a 6” square of aluminum foil, plate or aluminum can. Sand the can to remove paint and plastic barrier on the inside.
2. Place the aluminum on a soft surface and poke holes all over it to allow air to penetrate.
3. Add a 6” square of paper towel on top of the aluminum.
4. Add a ½” thick mound of ground briquette or activated charcoal about the texture of course corn meal. You can wrap the charcoal in paper and pound with a hammer to shatter the lumps.
5. Place copper strip in the center of the mound so that it doesn’t touch the bottom and 2” sticks out above.
6. Fold the paper towel over the charcoal pile at the bottom to prevent it from fall out later.
7. Roll the aluminum around so that the copper electrode is in the center of the mound of charcoal and does not touch the aluminum. Tie the tube with a twisty tie or a piece of wire. The top of the tube should be open with the charcoal and copper wire exposed.
8. Place the battery in a plastic cup.
9. Pour saturated salt electrolyte into the charcoal core until you have about 1” at the bottom of the cup.
10. Connect clip leads to the center copper lead and to the top of aluminum tube, and then to an electric meter.
11. Connect several cup cells together going the copper lead of one to the aluminum lead of the next. Measure the voltage at the end of the chain as each cell in inserted. When you reach 2-3 volts you may be able to light the LED.



Flat Cell battery sandwich design

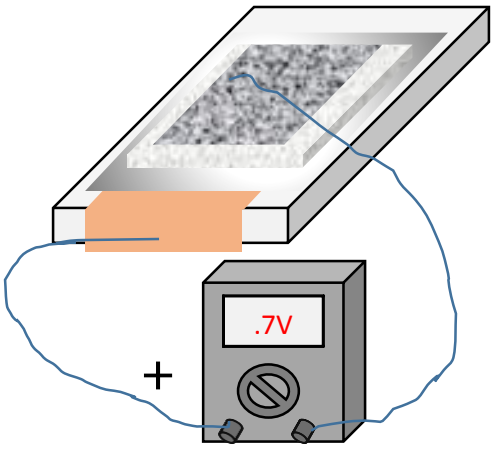
This format looks more like a battery but is a little more fussy to build and will not run as long because the electrolyte dries out. It offers some interesting design challenges to consider how to make the technology practical. How can you be sure each cell connects with the next. How can you increase the air reaching the cell. Where is the aluminum most reacted.

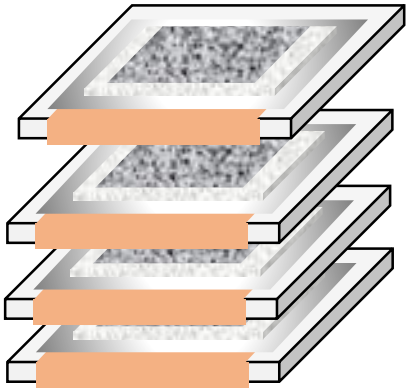
1. Cut 1" squares of stiff plastic, 1" squares aluminum foil, plates or aluminum cans that have been sanded.
2. Cut 1" filter paper or paper towel and position this in the middle of the aluminum square being careful not to have it stick out beyond the edge of. Wet the paper with the salt electrolyte solution.

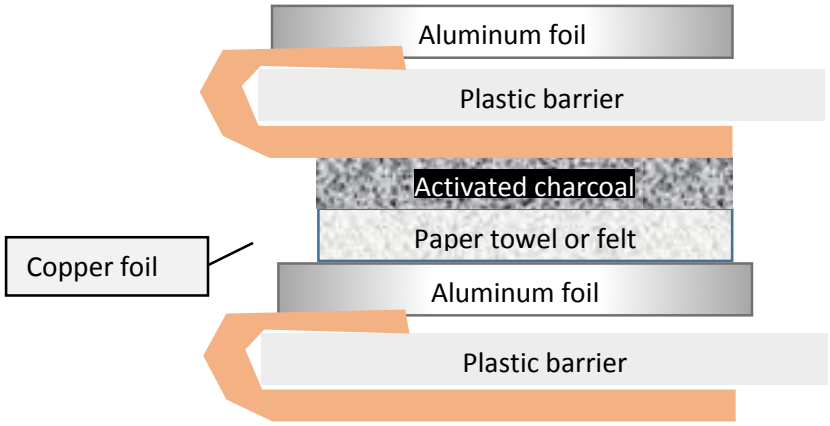


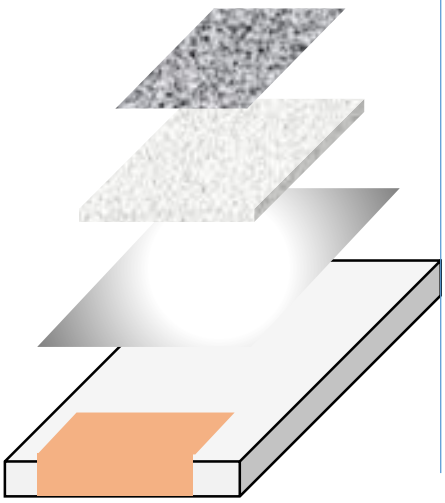
3. Grind up the charcoal to make medium grain powder like cornmeal or obtain powedered graphite. Spoon about 1/8" thick layer on to the top of the paper. Wet the carbon with electrolyte.
4. Cut 1.5" x1" long strip of copper foil or tape. Wrap this around the plastic square so the copper foil is exposed on both sides. Add the copper covered plastic to the stack so that the copper touches all the carbon. This constitues one cell which should produce about .7 volts with saltwater electrolyte

5. Add multiple cells in a neat stack. Pinch the whole pile with rubberband. Connect the copper foil on the top and the aluminum foil on the bottom with clip leads to an LED and/or electric meter.









Coin Cell – Petri Dish Model

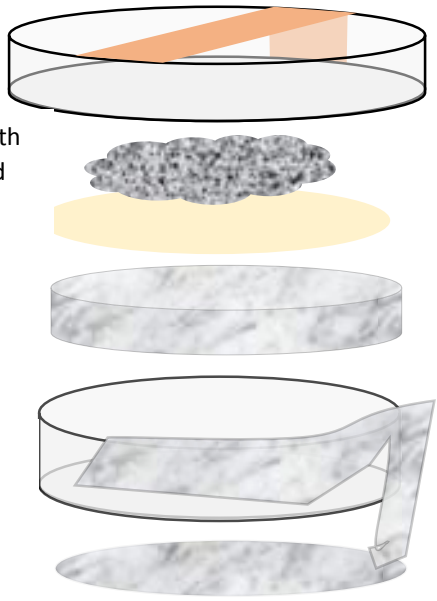
Coin cells are small batteries often used for hearing aids or other small electronic devices. They are also used in research as convenient way to test combinations of electrode materials and electrolytes. Hundreds of coin cells may be A real coin cell has a metal housing that is separated by a rubber gasket from the central electrode. In this model cell a plastic petri dish serves as the shape of the cell and to contain the liquid electrolyte.

1) Cut a strip of aluminum foil and wrap it from the inside of the smaller tray around to the outside of the bottom. Crumple some aluminum foil and press it firmly into the smaller petri dish filling it to near the top.
2) Cut a circle of paper towel or felt and place the crumpled aluminum.
3) Wet a cotton ball with electrolyte and place it on the paper towel.
4) Sprinkle activated charcoal powder or powdered graphite on the cotton ball.

5) Attach a strip of copper foil from the inside of the petri dish top around to the outside. As you bend the internal corner press it firmly into the angle before attaching the rest so that the copper does not bridge open air. This is a common failure point because the bottom will cut the copper strip when the lid is pressed down resulting in an open circuit.
6) Add more electrolyte to saturate the cotton ball. When the lid is added the ball should press gently against the copper strip
7) Test the voltage of each cell.
8) Stack the cells. The copper foil on the top of each should touch the aluminum of the bottom of the one above.

9) Run a wire and led from the aluminum foil of the bottom most cell, to the copper foil of the top.
10) It may take 5 or 6 cells to get enough voltage to light the LED.

Petri top with copper foil going from the top, around the side, to inside of the

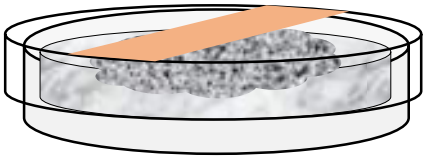


Cotton ball saturated with electrolyte and sprinkled with activated charcoal.

Paper towel or felt

Crumpled aluminum foil

Aluminum foil wrap around petri bottom



Design Questions to Explore

How can you increase the availability of oxygen to the cell?

How can you improve the contact between the current collector (copper) and the charcoal layer.

Is there a limit to the series voltage a chain of these batteries can achieve?

How does the pH of the solution change as the reaction proceeds?

Is there an advantage to using a flowing or circulating electrolyte?

Citations

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