To ensure that a student-designed car, which is powered by zinc carbon batteries and stopped by an iodine clock reaction, travels a prescribed distance with a designated load in a safe and competitive manner.

BACKGROUND CHEMISTRY

Zinc Carbon Batteries

In our ChemE Car, we used an array of zinc-carbon batteries as our power source. Zinc-carbon batteries are a primary electro-chemical battery chemistry in which power is produced from the oxidation of zinc.

The overall reaction is shown below:

Overall: $Zn + 2MnO_2 + 2H_2O \rightarrow Mn_2O_4 + Zn(OH)_2 + H_2 \ (E_{cell} = 1.5V)$

In a zinc-carbon cell, zinc forms the anode of the battery. The carbon is a nonreactive component of the cathode that acts as a current collector. The carbon is surrounded by the electrolyte, composed of a paste of manganese dioxide and ammonium chloride.

Anode: $Zn \rightarrow Zn^{2+} + 2e^- \ (E_c = -0.762V)$

Cathode: $2MnO_2 + 2e^- + 2H_2O \rightarrow Mn_2O_4 + 2OH^- \ (E_c = +0.5V)$

Iodine Clock Reaction

The iodine clock reaction begins when two solutions are mixed:

A. 3% $H_2O_2$ and 0.18M $H_2SO_4$
B. KI, Na$_2$S$_2$O$_3$, and corn starch

The reaction system is comprised of two reactions occurring simultaneously:

1. $H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$
2. $2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_2O_4^{2-}$

The triiodide ion formed in reaction 1 is immediately consumed in the faster reaction 2. Na$_2$S$_2$O$_3$ is the limiting reactant for this system. When all of the S$_2$O$_3^{2-}$ is consumed, the I$_2$ will form a dark purple complex with the corn starch, turning the solution from clear to an opaque purple (Figure 2).

Iodine Clock Reaction Setup

The Iodine Clock Reaction Chamber

- A black box isolates the reaction solution from ambient light.
- Holes were drilled in top of the black box and the top of the lid of the reaction vessel to allow a syringe to inject a solution into the vessel.
- The syringe needle is permanently mounted to the black box.
- A flashlight and a photo-resistor are positioned horizontally on opposite sides of the black box.
- The photo-resistor is connected to an Arduino microcontroller.

Zinc Carbon Battery Setup

A total of eight zinc-carbon cells are used in Junk in the Trunk.

- Each cell is housed in a petri dish with components arranged as depicted in Figure 4.
- Clamps are used to hold each pair of cells together and inserted into a custom built stand within the battery box.

Each pair of cells is connected in parallel to increase current. The four pairs are then connected in series to increase the total voltage (Figure 5).

Safety Considerations

- Use proper PPE when setting up and operating Junk in the Trunk.
- Avoid exposed electrical connections by not using alligator clips.
- Dispose chemicals in properly labeled waste containers.

Recommendations

- Use clamps to ensure good contact between all components of battery.
- Use CLR to clean built up oxide layers off of the zinc plates.
- Do not reuse fabric membranes.
- Use electrical tape to cover exposed electrical connections and prevent shorts.
- Use a geared down motor in the chassis.

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