CornellEngineering
School of Chemical and Biomolecular Engineering

2018 Eckhardt Northeast Student Regional Conference | April 7-8 | Rochester, NY

THICCC PB

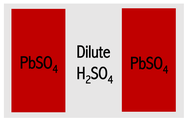
Cornell ChemE Car Team Members:
Senior Captain Jessie Reeves, Junior Captain Jordan Fuller, Jonathan Ong-Siong, Brayan Pena, Judson Friedl, Doris Chen, Tara van Nieuwstadt, Alan Chen, Alex Chi, Courtney Bui, Rose Yin, Kathy Chen, Kevin Cavallo, Kevin Klaben, Erika Mills, Sophie Arzumanov, Linda Li, Olivia Roberts, Brian Jeong, Jiayao Wu, and Chris Wright

CORNELL CHEME CAR

POWER SOURCE

The vehicle is powered by a lead-acid battery. There are four cells contained in each of two Ball® pint-sized mason jars. The cells consist of lead plates and 6 M sulfuric acid. The lead plates are separated by fiberglass. The net electrochemical reaction powering the car's motion is:

$$Pb_{(s)} + PbO_{2\,(s)} + 2H_2SO_{4\,(aq)} \rightarrow 2PbSO_{4\,(s)} + 2H_2O_{(l)}$$

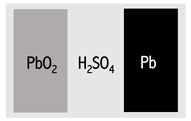


Positive Plate Reaction

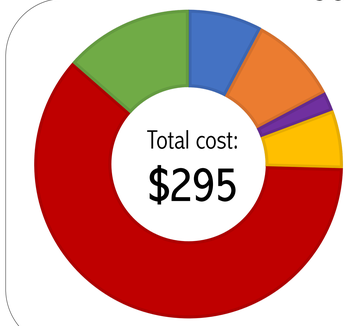
$$PbO_{2\,(s)} + HSO_{4\,(aq)}^{-} + 3H^{+}_{(aq)} + 2e^{-} \rightarrow PbSO_{4\,(s)} + 2H_2O_{(l)}$$

Negative Plate Reaction:

$$Pb_{(s)} + HSO_{4\,(aq)}^{-} \rightarrow PbSO_{4(s)} + H^{+}_{(aq)} + 2e^{-}$$



COSTS

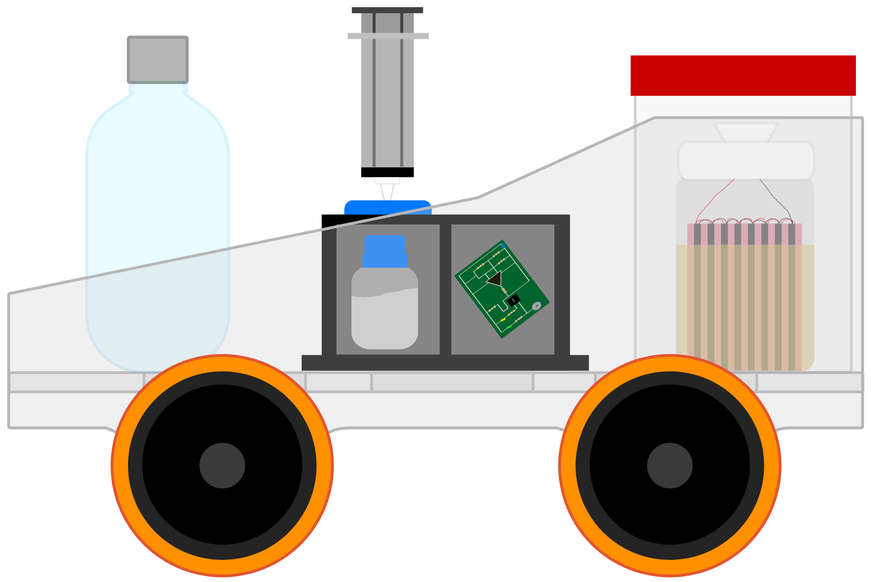


Sulfuric acid	$23
Lead plates	$28
Fiberglass separator	$6
Mason jars	$18
Chassis & Drivetrain	$180
Stopping mechanism	$40

ENVIRONMENTAL IMPACT

- Can use recycled materials for battery construction
- Emission-free power source
- Highly efficient chemical energy conversion

CAR DESCRIPTION



The car chassis is an acrylic base with a motor, axle, and wheels. The batteries, stopping mechanism, and circuit are secured on top in containments. The batteries are contained in glass pint-sized mason jars and plastic lids.

SAFETY FEATURES

- Proper protective equipment (pants, closed toed shoes, splash goggles, gloves, and hair ties) is worn at all times when working with the car.
- Chemical resistant gloves are worn whenever handling sulfuric acid. The sulfuric acid is poured into the mason jars using a funnel while under a fume hood.
- The iodine clock reaction vessel has a secondary containment immediately around the vessel.
- The batteries have a secondary containment casing.
- All moving parts of the motor are surrounded by the chassis and will not be accessible to hands.
- There is no exposed wiring on the car.

STOPPING MECHANISM

Iodine Clock Reaction

The iodide ion is generated by the following slow reaction between the iodate and bisulfite:

$$IO_{3(aq)} + 3HSO_{3(aq)} \rightarrow I^{-}_{(aq)} + 3HSO_{4(aq)}$$

Rate-determining step: The iodate in excess will oxidize the iodide generated above to form iodine:

$$IO_{3\,(aq)} + 5I^{-}_{(aq)} + 6H^{+}_{(aq)} \rightarrow 3I_2 + 3H_2O_{(l)}$$

However, the iodine is reduced immediately back to iodide by the bisulfite:

$$I_{2\,(aq)} + HSO_{3(aq)} + H_2O_{(l)} \rightarrow 2I^{-}_{(aq)} + HSO_{4(aq)} + 2H^{+}_{(aq)}$$

When the bisulfite is fully consumed, the iodine will survive (i.e. no reduction by the bisulfite) and the solution will darken. Then the power to the motor is cut and the car stops.

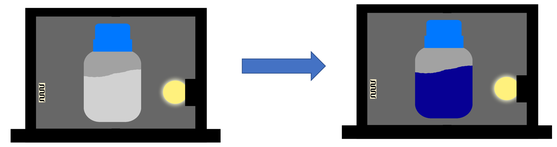
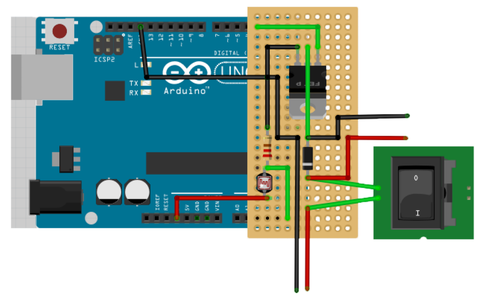


Photo resistor detects light — Solution cuts off light

CIRCUITRY



The photo resistor detects light passing through the stopping mechanism solution. The Arduino reads this and triggers the transistor to open the circuit when the solution turns dark blue. This cuts off power to the motor, causing the car to stop.

A Special Thanks to: Professor Abraham Stroock, Robert Frederick Smith School of Chemical and Biomolecular Engineering, Cornell College of Engineering, Cornell Student AIChE Chapter, Leeds and Hess Family, Alumni Family

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FULLY CHARGED

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CORNELL CHEME CAR

POWER SOURCE

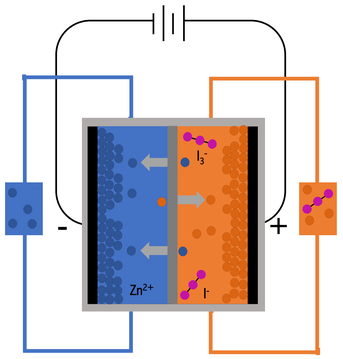
The car is powered by a zinc-polyiodide flow battery. The battery consists of two charged solutions, one with zinc ions and one with iodide ions that circulate through the half cells using peristaltic pumps. The half cell reactions are:

Cathode:
$I_3^- + 2e^- \longleftrightarrow 3I^-$ $\quad E° = 0.5360V$ or SHE

Anode:
$Zn \longleftrightarrow Zn^{2+} + 2e^-$ $\quad E° = -0.7626V$ or SHE

Overall:
$I_3^- + Zn \longleftrightarrow 3I^- + Zn^{2+}$ $\quad E° = 1.2986V$

The theoretical voltage per cell is 1.3V. There are multiple cells in series that are 3D printed in one half cell piece. The battery is compressed with silicon gaskets and acrylic plates and tested to be leak proof. There are membranes between the half cells that allow for ion transfer.



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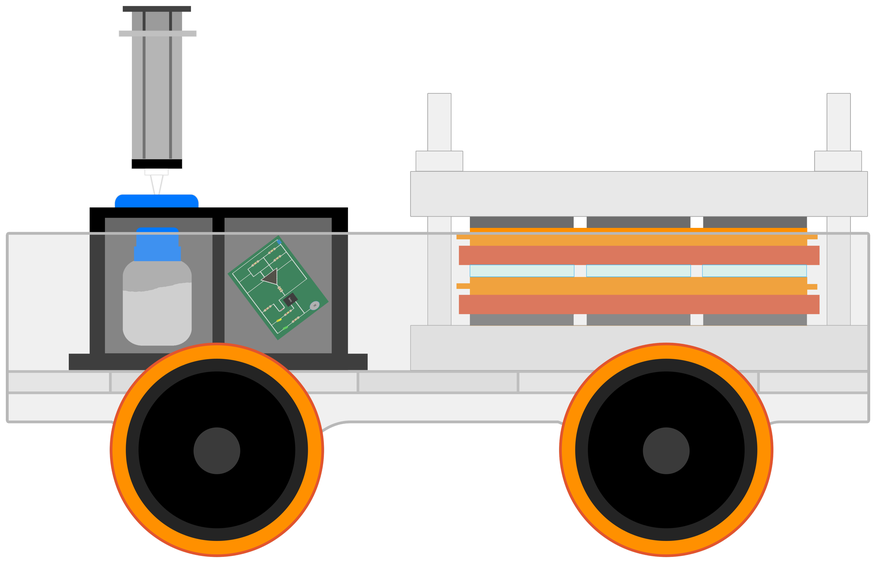

The car's chassis consists of an acrylic base with the motor, axle, and wheels attached to the bottom. The batteries, stopping mechanism, circuit board, and water load are secured on top of the acrylic board in containments. Most containment and parts are custom made from acrylic or ABS plastic. An acrylic gearbox cover contains all moving parts of the motor.

STOPPING MECHANISM

Iodine Clock Reaction

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$$IO_{3(aq)} + 3HSO_{3(aq)} \longrightarrow I^-_{(aq)} + 3HSO_{4(aq)}$$

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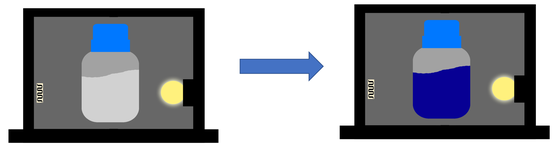

Photo resistor detects light | Solution cuts off light

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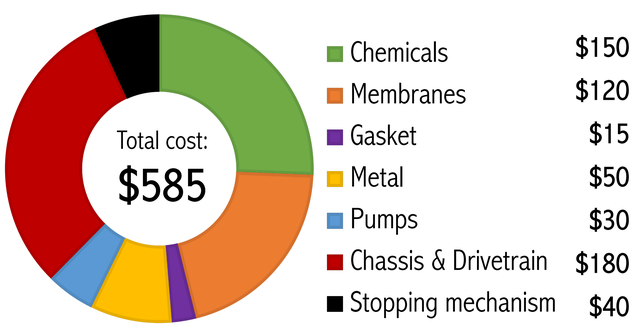
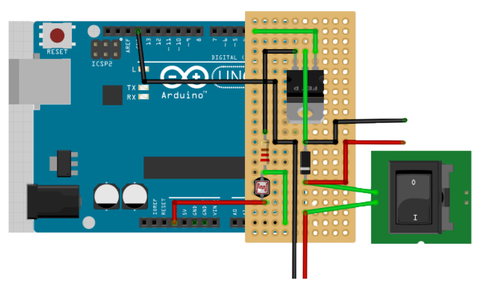


SAFETY FEATURES

- The iodine clock reaction vessel and the liquid reservoirs of the battery have secondary containment.
- The battery has absorbent sponges to ensure that any leaking will be contained.
- All moving parts of the motor are surrounded by the chassis and are not accessible to hands.
- There is no exposed wiring on the car.
- None of the components of the battery present extreme safety hazards, however, students still wear proper protective equipment (pants, closed toed shoes, splash goggles, gloves, and hair ties) at all times.

CIRCUITRY



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