Safety Considerations

When implementing the Standard Operating Procedure (SOP) outlined for battery assembly, it is crucial to prioritize safety measures to prevent accidents and ensure a secure working environment. Here are the safety considerations that should be observed:

1. ***Personal Protective Equipment (PPE)***: Ensure that all team members are equipped with the necessary PPE, including lab coats, lab goggles, nitrile gloves, pants covering ankles, and closed-toe shoes to protect against chemical exposure and physical hazards.
2. ***Respiratory Protection:*** N95 respirators have to be worn when handling Activated Carbon and during metal sanding
3. ***Contamination Control:*** Isolation gowns have to be worn when handling Activated Carbon and the gown has to be disposed of immediately to prevent the spreading of Activated Carbon powder
4. ***Accident Reporting:*** Any incidents, such as spills, injuries, or equipment damage, must be immediately reported to the supervising instructor.
5. ***Workspace Management:*** Maintain a tidy and unobstructed workspace to prevent accidents and ensure clear pathways in the lab.
6. ***Personal Conduct:*** Secure long hair and loose clothing to prevent entanglement or contact with chemicals or flames. Remain focused and avoid distractions while following the SOP.
7. ***Handling Sharp Objects:*** Utilize cut-resistant gloves when using scissors or handling sharp objects to prevent cuts and lacerations.
8. ***Chemical Handling:*** Exercise caution when dealing with chemicals, such as the 1.5M KOH solution, to prevent spills and skin contact. Dispose of chemical waste in accordance with the SOP and local regulations.
9. ***Material Use:*** Be aware of the limitations of materials, such as the safe temperature range for aluminum foil, to avoid accidents like overheating.
10. ***Battery Assembly:*** Ensure proper assembly of batteries to prevent short circuits. Only the tabs should make contact during cell assembly to avoid short-circuiting and performance degradation.
11. ***Safety Equipment:*** Familiarize yourself with the location and operation of safety equipment, including fire extinguishers, eye wash stations, first aid kits, and safety showers.
12. ***Prohibited Actions:*** Horseplay and unauthorized experiments are strictly forbidden to maintain a safe working environment.

By adhering strictly to these safety considerations throughout the SOP's execution, teams can mitigate risks, protect personnel from harm, and ensure a safe working environment conducive to successful battery assembly operations.

Chemicals Provided

Potassium Hydroxide (1.5 M), *600 mL by default. Extra can be requested but not guaranteed*
Calcium Hydroxide (100% pure, powder)
Citric Acid (100%, powder)
Sodium Citrate (100%, powder)
Carbon Black/Activated Carbon Powder Mixture

Non-chemical Materials Provided

Aluminum Foil (1 roll, 75 ft^2)
Copper Wire Mesh (1 m^2)
Paper Towel (1 roll)
Tablecloth (2 count)
Elmer’s School Glue (120 g)
Elmer’s Probond Glue (1 bottle, 4 oz.)
Zinc Plates (20 count)
Scissors (2 pairs)
Insulated Alligator Clips (30 count)
100 grit sandpaper (1 sheet)

Personal Protective Equipment Provided

Cut-Resistant Gloves (2 pairs)
Apron/Isolation gown
N95 Masks
Sleeves

Part 1 - Material Preparation

Anode (Aluminum or Zinc)

Aluminum Anode

1. Using a sharpie, trace the desired shape and size of the anode on the aluminum foil.
2. Using a pair of scissors, cut the aluminum foil to the desired size and fold the piece in half. **Wear cut-resistant gloves during the cutting process.**
3. Repeat until the desired number of anodes is achieved (depending on the testing conditions).

Zinc Anode

1. Using a sharpie, trace the desired shape onto the zinc plate.
2. Using a pair of scissors, cut the zinc plates to the desired shape. **Wear cut-resistant gloves during the cutting process.**
3. Repeat until the desired number of anodes is achieved (depending on testing conditions).
4. If zinc plates have been previously used, it is advised to sand off any zinc oxide to improve performance. **Wear cut-resistant gloves during sanding.**

Cathode (Copper Mesh with Applied Carbon Powder)

1. Using a sharpie, trace the desired shape onto the copper wire mesh. It is advisable to match the shape to that of the chosen anode.
2. Using a pair of scissors, cut the copper wire mesh along the black lines.
3. Wrap the tab in masking tape to prevent any carbon powder from being applied to the tab.
4. At a ratio by mass (between 1:1 to 1:6), add Elmer's ProBond Glue and Elmer's School Glue to a plastic container using an analytical balance.
5. Add 4 caps (approximately 8 g) of carbon powder mixture per 20 g of glue mixture, then mix thoroughly until a homogenous paste is formed. **Note: Please notify leads if the carbon powder mixture is depleted, we will prepare more for you!**
6. Apply carbon paste to copper wire mesh from step 3, covering all exposed copper. Hang up the cathode to dry.
7. Repeat until the desired number of cathodes is achieved.

Electrolyte (Potassium Hydroxide with Additives)

1. Obtain the 1.5M KOH stock solution. Please only take what is required to minimize chemical waste (10-15 mL per cell is enough).

For the purposes of this SOP, an example mass of 0.1 g of each additive will be used. You may vary the mass of each additive, but DO NOT EXCEED 0.75 g-additive per 100 mL.

Aluminum Anode

1. Using an analytical balance and a weighing boat (or weighing paper), weigh out 0.1 g sodium citrate and 0.1 g calcium hydroxide per 100 mL of 1.5M KOH.

2.1 Standard operating procedure (SOP) for battery assembly and testing

Zinc Anode

1. Using an analytical balance and a weighing boat (or weighing paper), weigh out 0.1g potassium carbonate and 0.1g citric acid per 100 mL of 1.5M KOH.

General

1. Transfer the additives to the 1.5M KOH solution and use a 30 mL syringe to stir the solution until the additives have dissolved.

Paper Towel

1. Based on the size of the previously prepared anodes and cathodes, cut paper towels to match, ensuring double-layering. Note: tabs should not be included on the paper towel. **Ensure that the paper towels are large enough to cover the electrode surface, but not too large. Overhang may lead to short-circuiting in the battery.**
2. Repeat until the desired number of paper towels have been prepared.

Cell Separator

1. Cut the tablecloth to the appropriate size based on the anodes, cathodes, and paper towel.
2. Using masking tape, attach 2 tablecloths to each other, with plastic-like sides facing outwards.
3. Repeat until the desired number of cell separators have been prepared.

Part 2 - Battery Assembly

1. Review the following checklist to ensure that all materials have been prepared. Lay out these materials on the workbench, ensuring that the area is safe (no chemicals on the workbench, no congestion/traffic in the nearby area, etc.).
    a. **All PPE is being worn (lab coat, lab goggles, nitrile gloves, pants covering ankles, closed-toe shoes).**
    b. Anodes (either aluminum or zinc).
    c. Cathodes with applied carbon powder.
        i. Carefully remove the masking tape on the tab. Do not rush, as this could lead to ripping the tab and having to make a new cathode again.
    d. Paper towels (double-layered).
    e. Tablecloth cell separators (double-layered).
    f. 1.5M KOH solution with additives (sodium citrate and calcium hydroxide if using aluminum anode, potassium carbonate and citric acid if using zinc anode).
    g. Alligator clips.
    h. Multimeter (for testing performance after assembly is complete).
    i. Black and red wires with crimp connections (not needed if not connecting to the car).

2.1 Standard operating procedure (SOP) for battery assembly and testing

During assembly, it is VERY IMPORTANT that CELLS ONLY MAKE CONTACT AT THE TABS. If there are other contact points, the battery will most likely short circuit and the performance will significantly decrease.

2. Lay down a cell separator.
3. Lay down a cathode with the tab opposite that of the cell separator.
4. Using an alligator clip, attach the cathode tab to the previous anode tab. If this is the first cell, there will be no previous anode.
5. Lay down a double-layered paper towel on the cathode.
6. Using the 30 mL syringe, carefully apply approximately 10 mL of the electrolyte solution, covering the entire surface area.
7. Lay down the anode, ensuring that the tab is opposite to the previous cathode tab.
8. Lay down a cell separator, ensuring that the tab is opposite to the previous anode tab.
9. Repeat steps 3-8 until the desired number of cells have been constructed.
10. If the battery is being used to power the car, attach the red crimped wire to the positive terminal and the black crimped wire to the negative terminal of the battery.

Part 3 - Battery Testing

Voltage Testing

1. Attach the input of the red lead to the voltage testing port of the multimeter.
2. Attach the input of the black lead to the COM port of the multimeter.
3. Set the multimeter to the “DC Voltage” mode (typically denoted by $\bar{V}$)
4. Attach the red lead to the positive terminal of the battery, then the black lead to the negative terminal of the battery. The battery voltage should now be displayed on the screen.
    a. If the value is zero, ensure that the leads are connected to the correct ports and that the multimeter is in the correct mode.
    b. If the value is negative, ensure that the leads are connected to the correct battery terminals.

Amperage Testing

1. Attach the input of the red lead to the amperage testing port of the multimeter.
2. Attach the input of the black lead to the COM port of the multimeter.
3. Set the multimeter to the “AC/DC Amps” mode (typically denoted by A).
4. Attach the red lead of the positive terminal of the battery, then the black lead to the negative terminal of the battery. The amperage should now be displayed on the screen. **IMPORTANT: Do not test amperage for more than 1-2 seconds. This will drain the battery’s limited capacity.**
    a. If the value is zero, ensure that the leads are connected to the correct ports and that the multimeter is in the correct mode.

Part 4 - Attaching the Battery to the Car

1. Ensure that the red and black crimp wires are attached to the CORRECT BATTERY TERMINALS. The RED crimp wire should be connected to the POSITIVE terminal, and the BLACK crimp wire should be connected to the NEGATIVE terminal.
2. Carefully lift the battery from the bottom and transfer it to the battery box.
3. At this stage, it is advised to test the battery with the multimeter again to ensure that no cells have been shifted (i.e. short-circuited) during the transfer process.
4. Carefully lift the box and place it onto the car chassis.
5. Attach the red crimp connection to the corresponding red crimp connection (communicate with the circuitry and mechanical members of your team!).
6. When the car is brought to the start line, attach the black crimp connection. Doing so beforehand will unnecessarily drain the battery and may negatively impact your car's performance!

Part 5 - Battery Disassembly and Waste Disposal

If Battery was used on the Car

1. Disconnect the black crimp wire first, and then the red crimp wire.
2. Carefully remove the battery box from the car and transport it to the workbench.
3. Carefully remove the battery from the box and lay it on the workbench.
4. Disconnect all wires.

In all Cases

1. Remove all alligator clips and place them aside.
2. Remove each layer from the top down, separating the tablecloth, anode, cathode, and paper towel.
3. If zinc was the chosen anode, place the plates aside to dry in preparation for sanding for the next use.
4. Dispose of all chemically contaminated solid waste in the green plastic pail. **Confirm with leads before proceeding.**
5. Dispose of the extra KOH electrolyte in the basic aqueous waste container. **Confirm with leads before proceeding.**