2025 Engineering Design Package (EDP)

University: BITS PILANI, Pilani Campus	
Vehicle Name: VIRUS	
Team Captain Name: Aman Arora	**Team Captain Email:** amanarora09032003@gmail.com
Faculty Supervisor: Dr. Sarbani Ghosh	**Supervisor Email**: sarbani.ghosh@pilani.bits-pilani.ac.in
Revision #:	**Revision Date**:
***Onsite Safety Judge*:** (Virtual Only)	
***Onsite Track Length*:** (Virtual Only)	***Onsite Track Width*: -** (Virtual Only)

Instructions for Chem-E-Car Team:

- All Chem-E-Car Teams competing in an AIChE Chem-E-Car Competition must complete and submit an Engineering Design Package by the posted deadline.
- Failure to meet the posted deadline will result in exclusion from the competition.
- Please complete all the applicable sections of this document, and save in PDF format. If your EDP is incomplete, AIChE cannot guarantee that it will be reviewed.
- Please rename the title of the document using the format University Name EDP.
- Additional information including Safety Data Sheets (SDS), Manufacturer's specification documents or specifications for custom-built components should be compiled and saved as another single PDF titled "University Name EDP Supplement".
- All teams will receive EDP Feedback with any suggested changes from AIChE Chem-E-Car Competition Safety Judges.
- Please use the MOC Form document to document changes made to the EDP after receiving EDP feedback from your online review.
- Each team must bring a printed copy of final EDP, EDP Supplement, EDP feedback and MOC Form in a folder or binder. This will help streamline the Onsite Safety Inspection on competition day.
- *Please review the AIChE Code of Conduct and Code of Ethics.*

For more information, visit www.aiche.org/chemecar.

Job Safety Assessment Form

Car operation, hazards, and safety: Describe your Chem-E-Car's design, intended mode of operation (propulsion system), intended mode of control (stopping mechanism), auxiliary processes, major hazards and their control.

Describe your car's design:
Our Chem-E-Car has a compact design with overall dimensions of 30 cm x 20 cm x 15 cm (may vary). It includes a circuitry box housing the Nano microcontroller, 2 motor drivers, 1 voltage booster (not used to power the motor) to give nano exactly 5V from external battery There is an iodine clock chamber equipped with a solenoid valve for the stopping mechanism. The propulsion system consists of six to seven aluminium-air batteries connected in series to provide sufficient voltage. These batteries power the motor driver, which drives the 3W rated motor for movement. The design ensures stable operation with all components securely arranged on the car.

Power source (propulsion system):
The propulsion system of our Chem-E-Car is an aluminium-air battery. This battery generates electricity through the oxidation of aluminium at the anode and reduction of oxygen at the cathode, powering the motor for car movement.

The **anode** is aluminium metal, which undergoes oxidation during operation. The reaction at the anode is:
$2Al + 6OH^- \rightarrow 2Al(OH)_3 + 3e^-$ *(small amount of H2 gas is also evolved)*
Here, aluminium reacts with hydroxide ions from the electrolyte to form an aluminium hydroxide layer and release electrons.

The **electrolyte** used is a KOH-based agarose gel, which acts as an ionic conductor between the anode and the cathode, enabling efficient battery operation.

The **cathode** is prepared by first making two mixtures. The first mixture consists of a PVDF binder dissolved in DMF solvent. The second mixture contains activated carbon powder mixed with $KMnO_4$ catalyst. These two mixtures are then combined thoroughly to form a slurry, which is pasted onto a steel mesh to make the cathode electrode. At the cathode, the reduction reaction is:
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

The overall cell reaction is:
$4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$

Auxiliary processes including synthesized fuel production, battery charging, hydrogen production, etc. (if applicable):
As part of the auxiliary process, we prepare the agarose gel, which is used as the electrolyte in the aluminium-air battery for the propulsion system. It is a necessary step before assembling the battery in the car. Thus, preparing the gel forms an important part of our car setup process.

Stopping mechanism: An iodine clock reaction that results in a distinct color change once equilibrium is reached. The color change is utilized by a photo-resistor connected to an Arduino micro-controller to signal the end of the run to the motors.

Hazards inherent in design (for car & auxiliary processes, if applicable):
The **hazards in our car design are minimal**. The hydrogen produced from the aluminium-air battery is in very small quantities, which does not pose any safety risk under open conditions. Although hydrogen peroxide (>3%) is used in the iodine clock reaction. It is handled carefully in small volumes, minimising any potential harm. The KOH-based gel electrolyte is caustic in nature, but since it is incorporated in gel form, it is stable and does not spill or cause exposure. Overall, our car design is safe for operation with standard laboratory precautions in place.

Safety measures to prevent and mitigate hazards. Every hazard identified above must be addressed here:
We use chemicals in small, controlled amounts with proper PPE kits. The hydrogen produced is negligible and harmless, and KOH gel is stable and safe to handle. Hydrogen peroxide is used carefully in low volumes. Overall, hazards are minimal, and we continuously ensure safe operation. For the Iodine Clock reaction, 6mL of 30% Hydrogen Peroxide is used for each run, and we ensure complete safety of ourselves while using it. 2mL 0.02M Sulphuric Acid is also used in the iodine clock. Its low concentration and low volume makes it non hazardous.

Teams must implement a change in the reaction chemistry to both their propulsion and if applicable stopping reaction from the previous competition year.

Please list the major design changes for your car, and how the reaction chemistry of the propulsion and stopping mechanism (where applicable) has been changed from the car used in the previous year:
Last year marked our team's debut in the Chem-E-Car competition, and this year we have introduced significant upgrades to our design. We have transitioned our propulsion system from thermoelectric generators, which relied on temperature differences, to metal-air batteries, harnessing electrochemical reactions between metal and oxygen from air to generate electricity more efficiently. This shift not only enhances the power output but also improves the reliability and practicality of our car. Additionally, we replaced the acrylic chassis used last year with a precisely engineered 3D printed chassis with a light metal frame, making the car more compact, structurally robust, and easier to assemble. For the stopping mechanism, we are still using the iodine clock reaction but with a lower volume and with different concentrations of chemicals, which makes the reaction chemistry of the simultaneous reactions different. These improvements reflect our commitment to innovation and continuous development to achieve better performance in this competition.

For car & also for auxiliary processes if applicable

Expected Operating Conditions :
For the car, all operations occur at normal atmospheric pressure. In the auxiliary process, where we prepare the KOH-based agarose gel, the pH of the gel electrolyte is also around 12-13.

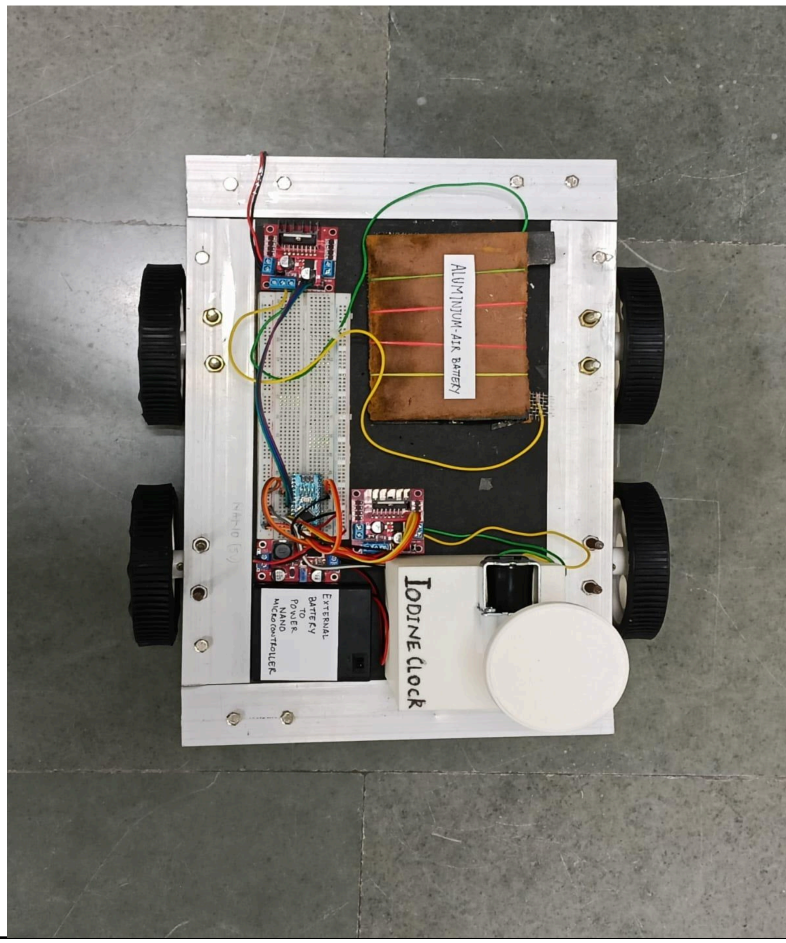
Temperature: For the car, operation takes place at room temperature without any significant heating. However, during the auxiliary process, while preparing the agarose gel electrolyte, we heat the agarose mixture to around 100-120°C on a heating plate/microwave to dissolve it completely before it is cooled and used in the battery.

If your car generates pressure above 5 psig, please list the Maximum Operating Pressure (MOP) and the Maximum Allowable Working Pressure (MAWP):
This question is not applicable to our car as it does not generate any pressure above 5 psig. The operating pressure remains at normal atmospheric conditions throughout all processes..

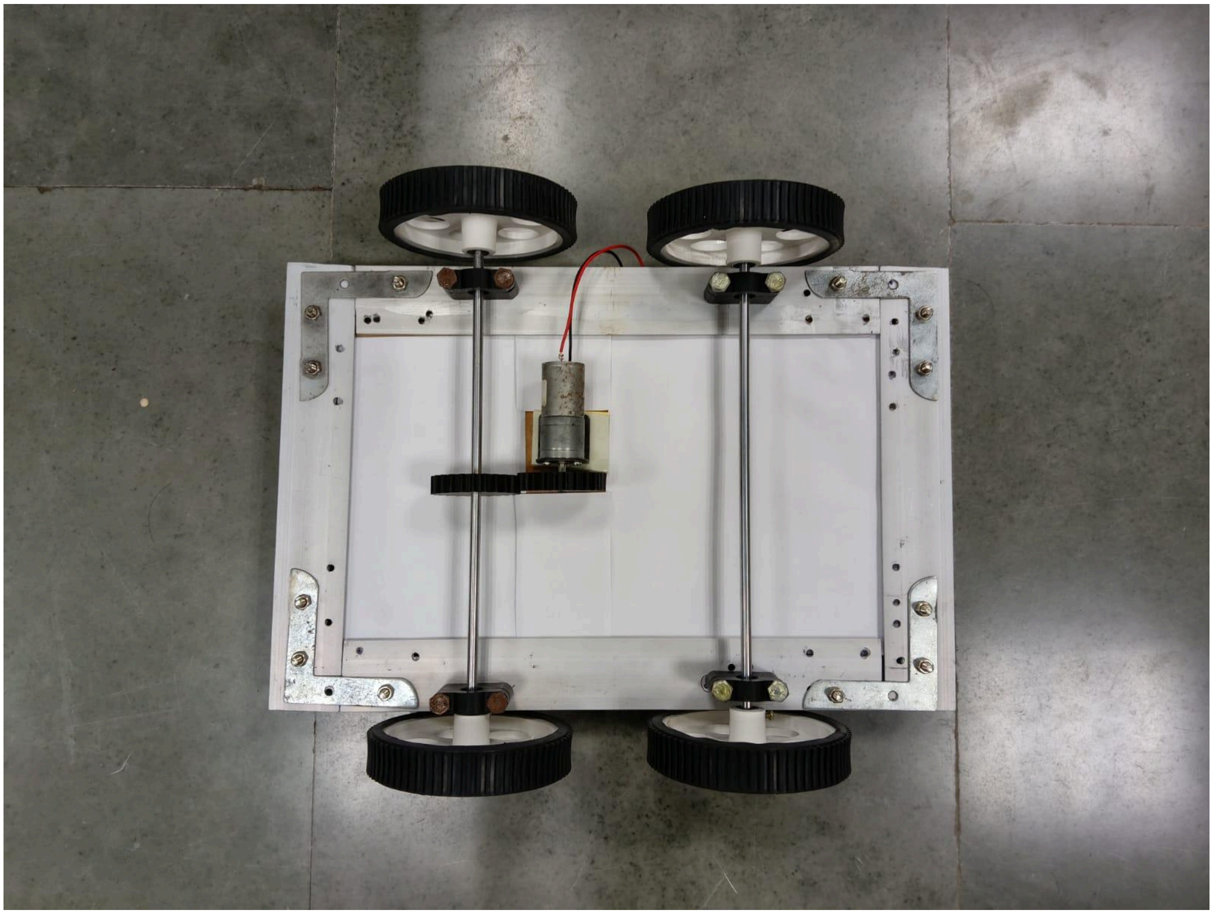
Photos of Completed Vehicle:

Please add photos of your vehicle <u>after construction has been completed</u>. These pictures must be current. The entire car must be visible in at least one picture. Remove the top to expose electrical controls if necessary. You must include multiple (at least 6) views of the car **(top, bottom, left, right, front and back**). Please adjust the following cells to fit *A drawing or AutoCAD document will NOT be accepted*

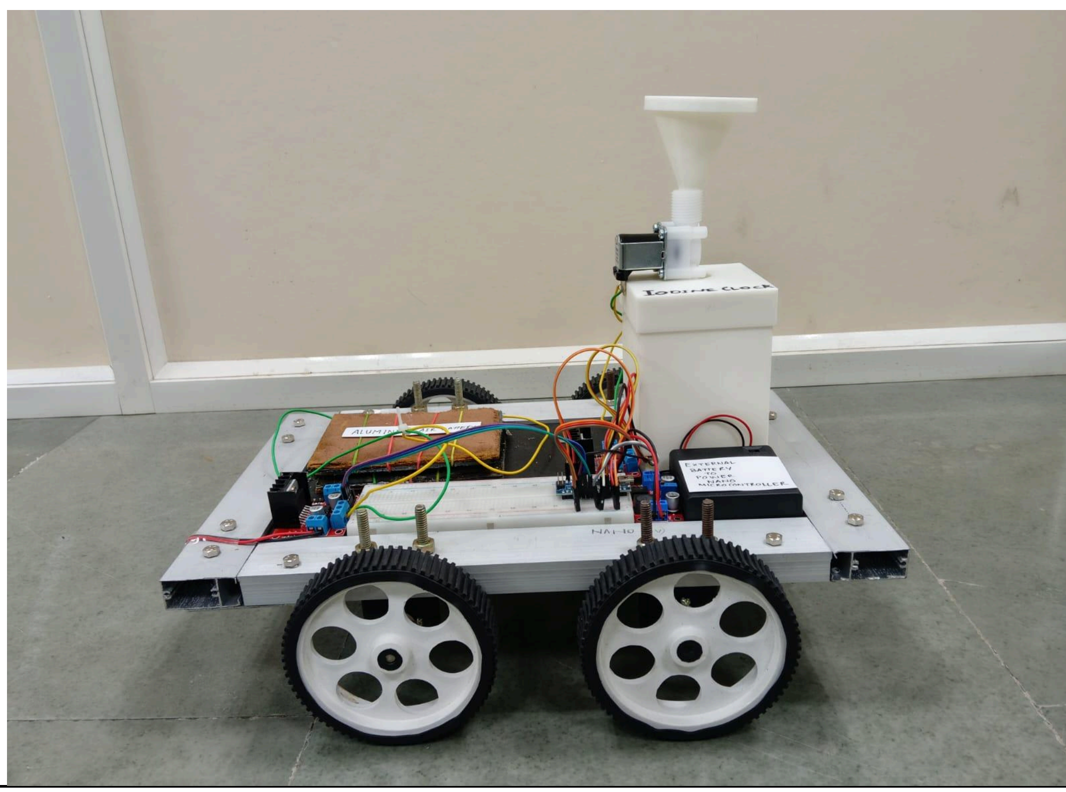
Top View



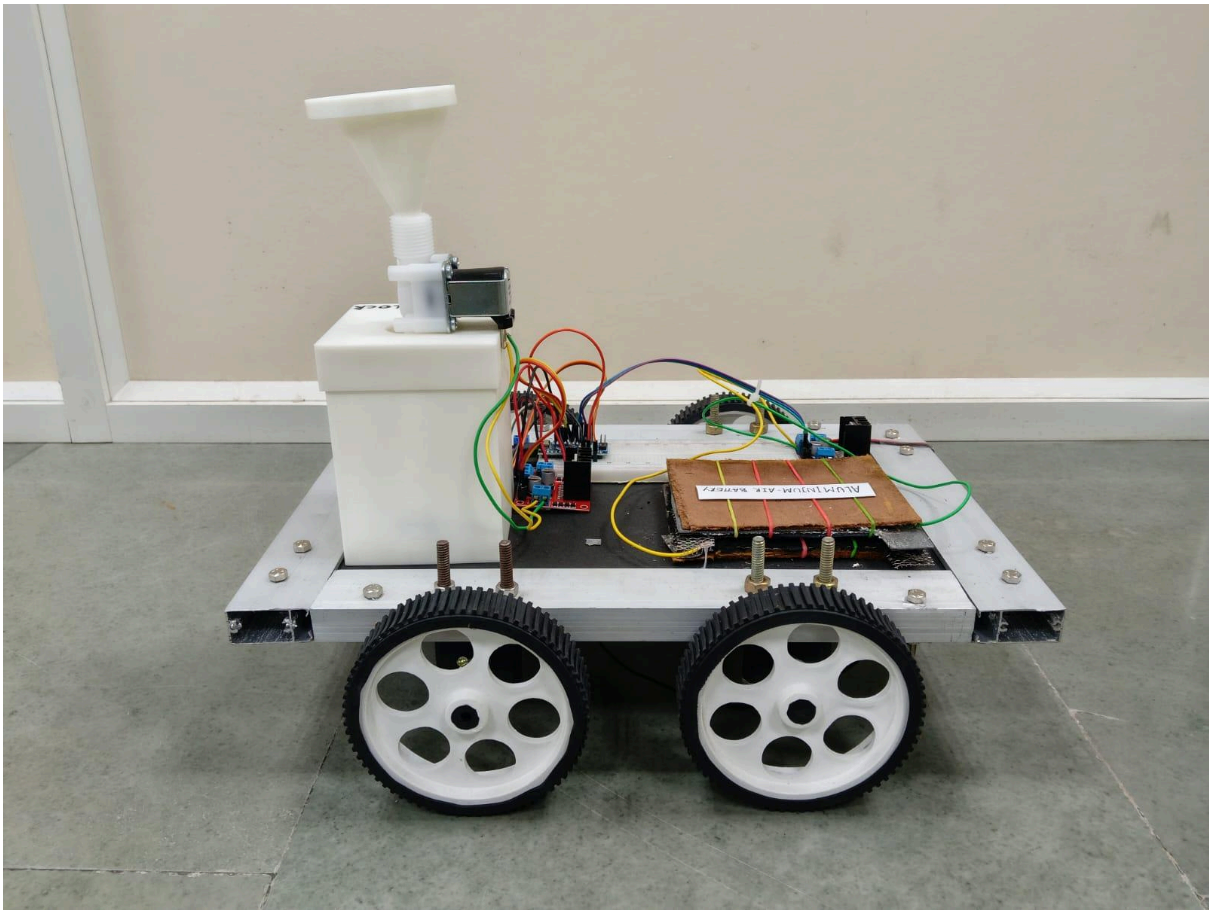
Bottom View



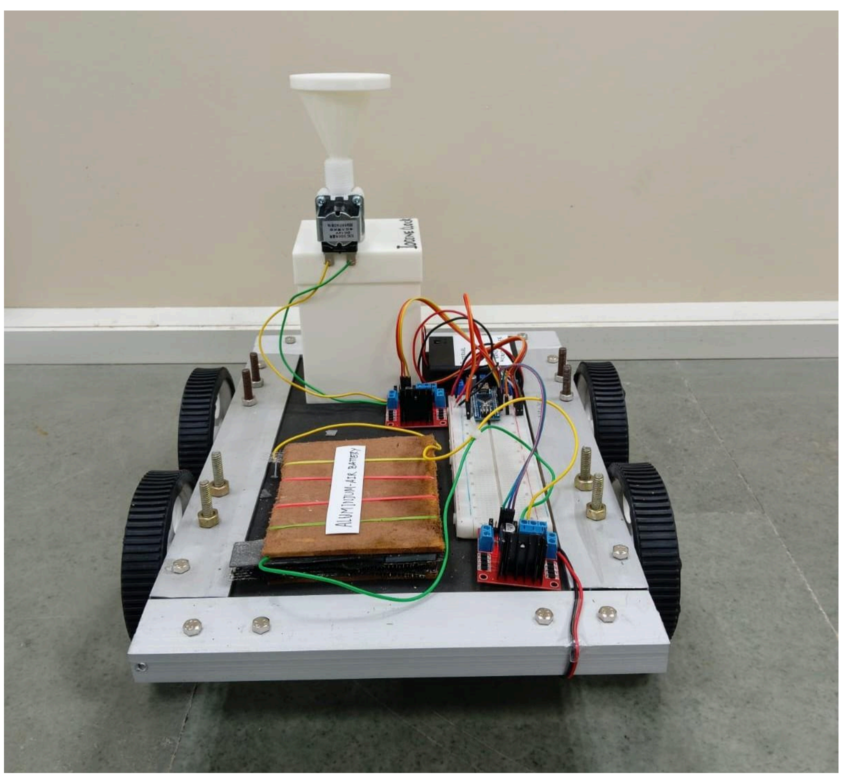
Left View



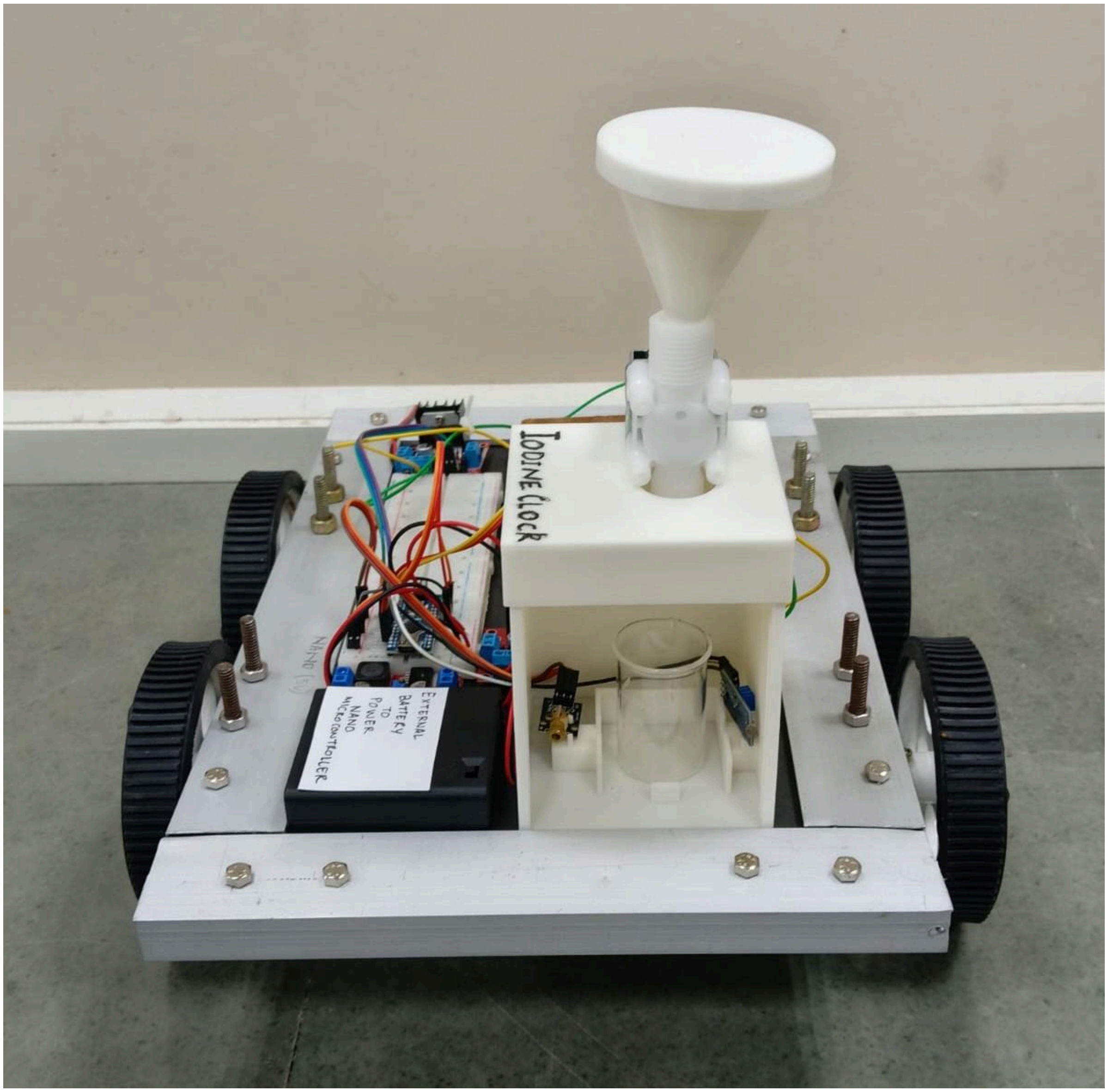
Right View



Front View



Back View



Request for Power Outlet at Competition Site (requirement for in-person competition): If your team requires a power outlet at your table at the competition, please provide reasoning here. *Please note that outlets requested to plug in laptops at your table will not be granted*.

For soldering purposes, heating plate.

Safety Training and Rules Certifications

University:	BITS PILANI, Pilani Campus	**Vehicle Name:** VIRUS

1. **Briefly describe the propulsion system (reaction/mechanism) of your vehicle.**

Aluminum Air battery is used as the propulsion system of the ChemE Car. The battery generates electricity through the oxidation of aluminium at the anode and reduction of oxygen at the cathode.
The reaction at the anode (aluminium) is:
$2Al + 6OH^- \rightarrow 2Al(OH)_3 + 3e^-$
Here, aluminium reacts with hydroxide ions from the electrolyte to form an aluminium hydroxide layer and release electrons.

At the cathode, the reduction reaction is:
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

The overall cell reaction is:
$4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$

The **electrolyte** used is a KOH-based agarose gel, which acts as an ionic conductor between the anode and the cathode, enabling efficient battery operation.

2. **Briefly describe the reaction that your vehicle uses to stop at the designated finish line.**

An iodine clock reaction that results in a distinct color change once equilibrium is reached. In the clock reaction aq. Potassium Iodide reacts with Sodium Thiosulfate, and starch to darken a solution after a set time. The timing depends on reagent proportions, calibrated using vehicle speed data. Sodium thiosulfate delays the color change by reacting with iodine and is adjusted to control the iodine clock. A photoresistor detects the darkening, triggering a relay that stops the car by disconnecting the motor and stopping the car.

Generation: $2I - + S2O8\ 2- \rightarrow I2 + 2SO4\ 2-$
Consumption: $I2 + 2SO4\ 2- \rightarrow 2I - + S2O8\ 2-$
Colour Change: $I2 + Starch \rightarrow Dark\ Solutio$m

3. **Provide a <u>precise answer</u> to the following question: If your vehicle is 3m short of the designated finish line on the first run, what <u>specific changes</u> will your team make to the stopping reaction to correct the shortfall?**

The speed of the car is 31.42 cm/s, so we need to increase time by 3 m/31.42 cm/s = 9.548 s so accordingly we'll change the volumes of chemical solutions used in iodine clock reaction. Specifically, to increase the time by 9.548s, we will increase volume of Sodium Thiosulfate by approximately 0.18g (as per our reaction concentrations)

4. **Required Safety Training:**
   All participants must take and pass the AIChE Chem-E-Car Safety Training Course with a minimum score of 80%. For information on the Safety Training Course, please visit www.aiche.org/chemecar.
   Please list the date that the required Chem-E-Car safety training that was completed by the faculty advisor:

Advisor Name	**Date**
Dr. Sarbani Ghosh	___________

Please list the date the required Chem-E-Car safety training that was completed by each team member:

Team Member Name	**Date**
Aman Arora	July 15, 2025
Tejus Manoharan	July 11, 2025
Navya Jain	July 15, 2025
Shreyansh Sharma	July 15, 2025
Abraham George	July 11, 2025
Nick Savio Fernandes	July 14, 2025
Tanmay Arora	July 13, 2025
Deva Nandan C	July 14, 2025
Tejus Arora	July 14, 2025
Chaitanya Patil	July 15, 2025
Manishankar	July 21, 2025
Sejal Gupta	July 21, 2025
Asmi Amit Kumar	July 21, 2025
Oorjit Gupta	July 21, 2025

5. **Faculty Safety Rules Certification:**
   I certify that this student team has followed all of the safety and competition rules, has completed an engineering documentation package, has completed a safety review under my supervision, and has at least ten hours of operating experience beyond the time required to design and assemble the car:

Faculty Advisor Name ___Dr. Sarbani Ghosh___________________________

Faculty Advisor Signature Sarbani Ghosh Date 21/07/2025

Outside Expert Name* NA____

Outside Expert Signature* ______________________________________ Date ________

**Note that this section must be signed by (1) Chem E Car Faculty advisor at a minimum. Having a signature from another outside expert is not required but recommended if you are getting support from another faculty member or safety professional on this project.*

6. Student Safety Rules Certification:

We certify that we have followed all of the safety and competition rules, have completed an engineering documentation package, have completed a safety review with our faculty supervisor, and have at least ten hours of operating experience beyond the time required to design and assemble the car. We understand and agree that we will not be allowed to compete in the Chem-E-Car Competition if our completed EDP package is not resubmitted by the posted deadline:

Team Member Signature Date

21 July, 2025

21 July, 2025

21 July, 2025

Navya Jain

Shreyansh Sharma 21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

21 July, 2025

Oorjit Gupta 21 July, 2025

Please include a copy of the Safety Training Course Certificate for each Team Member + Advisor in your EDP Supplement Document; Certificates should have a completion date of on or after January 1st 2025

Hazards Analysis

This analysis is for your home institution, not the competition site. Please attach a floor diagram of the laboratory where you will be building and testing your vehicle on the following page. List the location of available safety equipment and spill response supplies on this diagram.

Expected Operating Conditions:

Temperature	Pressure
Normal: R.T	Normal: 1 atm
Minimum: RT	Minimum: same as above
Maximum: RT	Maximum: same as above

Personal Protective Equipment (PPE): Check all PPE worn during operation of this Chem-E-Car. Do not list these in the procedure section.

☑ Long Pants	☑ Safety Glasses	☒ Hard Hat	☒Apron
☑ Long Sleeves	☑ Splash Goggles	☑ Insulated Gloves	☒Ear Protection
☑ Non-porous Shoes	☒ Face Shield	☑ Chemical Gloves	☒Other: NA

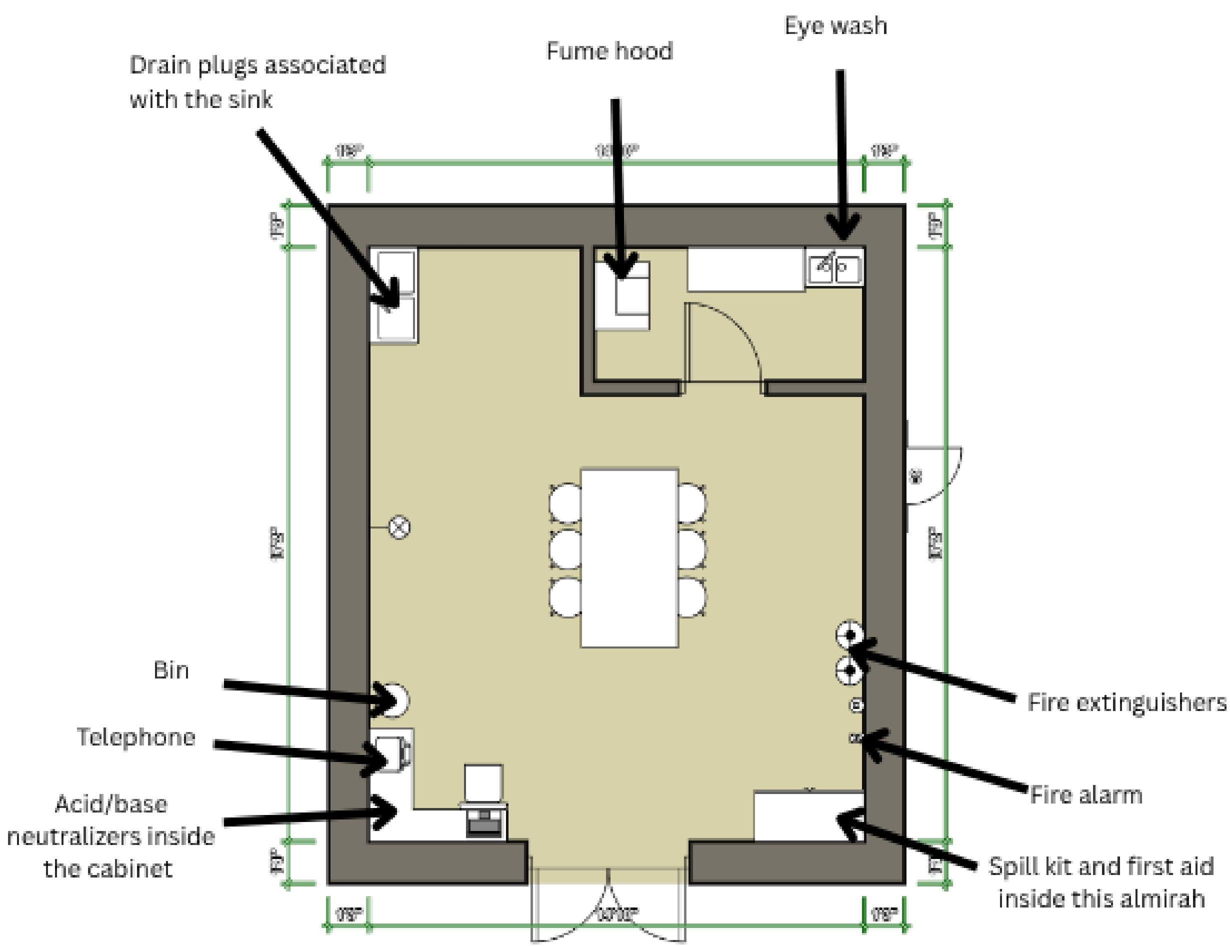
Available Safety Equipment – Provide the location of each item shown below at your home institution where your vehicle will be operated and tested. Show the location of this equipment on your provided floor plan. **Answer all questions**. If not available, type "NA" in the field.

Item	Location
Fire Extinguisher:	On the right side of the lab
Eyewash:	In the second section of the lab, top right corner
Safety Shower:	Just outside the lab, not shown in floor plan diagram
Telephone:	On the computer table (left side)
First Aid Kit:	Inside the almirah on the right
Spill Containment	Next to the lab in a store room, not shown in the F.P. diagram
Other: Fire Alarm	At the ceiling

Spill Response Supplies - Provide the location of each item shown below at your home institution where your vehicle will be operated and tested. Show the location of this equipment on the attached floor plan. **Answer all questions**. If not available, type "NA" in the field.

Item	Location
Spill Kit:	Inside the almirah on the right
Sorbent Powder:	NA
Spill Dikes:	NA
Acid and/or Base Neutralizers:	Inside the left cabinet
Drain Plugs:	At the left associated with th sink.
Spill Pillows:	With the spill kit
Mercury Spill Kit:	NA

Laboratory Floor Plan/Diagram: Please insert a floor plan diagram of the laboratory where you will be building and testing your vehicle on this page. List the location of available safety equipment and spill response supplies from the previous page on this diagram. Onsite Competition Fire & Safety Floor Plan showing the location of available fire and safety equipment as well as emergency exits in the performance competition venue will be provided to participating teams by the competition host.



Vehicle Primary Hazards Checklist: Check the box in the left hand column if the hazards listed below exist on the vehicle. Then check the applicable means of control for each hazard.

Hazard (check if present)	Control
☒ (a) Pressure *We are operating at normal pressure.*	Anything greater than 5 psig. **Must meet all requirements below:** ☐ Pressure gauge (must read to 2x max. operating pressure) ☐ Emergency relief device set to no more than 1.1 times the max. operating pressure. Relief sizing calculations must be provided. ☐ Emergency relief device in proper location. ☐ Pressure certification – see Pressure Vessel Testing Protocol ☐ Proper management system to prevent over or mis-charging. ☐ All car components exposed to pressure must be certified to operate at that pressure. Provide manufacturer's pressure specifications. ☐ No PVC, cPVC or polyethylene terephthalate (PETE or PET) plastics in pressure service or at all **Must have measurements or calculations to prove maximum operating pressure.** **Max allowable pressure this year is 200 psig.** **See ChemE car rules for more details on these requirements.**
☑ (b) Hazardous Materials.	Are any chemicals with a GHS hazard rating present (i.e., toxicity, flammability, corrosivity)? ☑ Doubly contained and handled properly. ☑ Team has properly filled out Team Waste Tags
☒ (c) Flammable Gasses.	Are flammable gasses/vapors used in the operation of the car? ☐ Components exposed to flammable gas (i.e. fuel cells) are purged with an inert gas prior to use. Must be detailed in operating procedures. ☐ No tied balloons are allowed (i.e. helium balloons)
☒ (d) Temperature *No temperature hazard.*	Any exposed surface greater than 150 deg. F or under 32 deg F. ☐ Insulation or barrier to prevent contact.
☑ (e) Electrical	Exposed wiring and electrically energized components are ignition, electrocution, and a shorting/fire hazard. Alligator clips and twisted wire connections are not allowed; use binding posts or banana plugs for a more secure connection. ☑ Proper electrical insulation and connections provided. ☑ Wires are neat and orderly to prevent tangles/snags
☑ (f) Electro Chemical (Battery)	Any student fabricated electrochemical devices (batteries) used on the car? ☑ Electrochemical device to be fully disassembled into original components and individual components made safe (pH=6-8) and disposed of separately. The team shall explain the process in detail. ☑ Team has properly filled out Team Waste Tags
☒ (g) Mechanical *No mechanical hazard*	Any parts (meshing gears, belts or chains) that are pinch hazards. ☐ Guards present and adequate.
☒ (h) Oxygen	All components exposed to oxygen. These must be ☐ certified for oxygen service. ☐ thoroughly cleaned of contaminants as per instructions in rules. ☐ not used previously for other types of service.

☒ (i) Biohazards	☐ No biohazards that require handling in a laboratory greater than Biosafety Level 1 (BSL-1) are permitted biohazard level 1 either during the design, development, preparation, or competition phases of your car.

Additional Fabrication & Operation Hazard Detail Check List: Check all hazards that are likely to be encountered during your Chem-Car construction and operation. List the major source(s) of the hazard and describe how the hazard(s) will be controlled. If both construction and hazard columns are checked in an individual row, then the hazards should be identified separately for both the construction and operation.

Hazard	Present During		Control Method(s)[1]	PPE Required[1]
	Constr-uction?	Operat-ion?		
Pressure	☐	☐		
Hazardous materials	☐	☐		
Hot Surfaces/High Temp > 150 F (65 C)	☑	☐	Using rubber butterfly to handle hot conical flask	Rubber hand protector
Cold Surfaces/Low Temp < 32 F (0 C)	☐	☐		
Electrical	☐	☐		
Arc welding	☐	☐		
Gas welding	☐	☐		
Lathe	☐	☐		
Milling machine	☐	☐		
Handheld power tools	☐	☐		
Drill press	☐	☐		
Other mechanical hazards	☐	☐		
Paint spraying	☑	☐	Using a mask, safety goggles and nitrile gloves to ensure spray paint won't cause any harm.	Mask, safety goggles and nitrile gloves
Ionizing radiation	☐	☐		
Laser radiation	☐	☐		
Asphyxiates	☐	☐		
Open flames	☐	☐		
Potential Spills	☑	☑	Chemicals used while creating solutions for the iodine clock solution may spill. Proper PPE kits are worn for student safety	Goggles, Gloves, Lab Coat, Full Pants, Shoes,

			and spill kits will be present to clean up and dispose off safely. The Iodine Clock Chamber contains 36mL of liquid. 6mL of solution B is dripped in 30mL solution A with the help of a solenoid valve. The iodine clock system contains a funnel *(3D printed with ABS material, then spray painted to avoid leakage)* at the top of solenoid valve is lined with PTFE tape	Spill Kit, Acid Neutralizers
Biohazards:	☐	☐		
Other:	☐	☐		
Other:	☐	☐		

Chemical Information Page

Description of Chemistry/Chemical Reactions: Provide details below on any chemical reaction(s) that occur in your system. Please show the reactants involved, the stoichiometry and the heat of reaction, if available. Also list side reactions and any other reactions that may impact safety.

Aluminium Air Battery:
At Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
At Anode: $2Al + 6OH^- \rightarrow 2Al(OH)_3 + 3e^-$
Overall Cell Reaction: $4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$
Side reaction: $2Al+6H_2O+2OH^- \rightarrow 2[Al(OH)_4]^- + 3H_2\uparrow$ *(H2 gas evolving)*

Iodine Clock Reaction:
Generation: $2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-}$
Consumption: $I_2 + 2SO_4^{2-} \rightarrow 2I^- + S_2O_8^{2-}$
Colour Change: $I_2 + Starch \rightarrow Dark\ Solution$m

Table 1: Please list all chemicals, concentrations and quantities that will be used at the competition site. Concentration MUST be that of the raw material being shipped, not your race day solutions. Select the check-box for any shipped chemicals. This is so the Host can prepare to receive, store and transport your chemicals.

Chemical Name	Chemical State (Sol/Liq/Gas)	Concentration/ Units	Amount (units)	Shipped to Host School (Yes/No)
Activated Carbon Powder	Solid	98%	250 g	yes
PVDF Polymer	Solid	100%	200 g	yes
DMF	liquid	99.8%	250 ml	yes
KMnO4	solid	99% w/w	100 g	yes
MnO2	Solid	99% w/w	100 g	yes
Agarose powder	solid	100% (Molecular Bio grade)	50 g	yes
Soluble Starch	solid	99%	100g	no
KI	solid	99%	250g	no
H2O2	liquid	30% w/w	250mL	no
H2SO4	liquid	98% w/w	250mL	no
Sodium Thiosulphate	solid	98% w/w	250g	no

Note: Please include any special storage requests that the Host should be aware of for your chemicals. Note these requests must be coordinated with the host school directly, stating them here is not sufficient.

We need to store the chemicals and equipment related to ChemE Car that we carry along with ourselves. Also, we need a microwave/heating plate a day before the competition to prepare the agarose gel as it is very delicate due to the reason we won't be able to carry it.

Table 2: Please list all chemicals that you expect to generate and dispose of during the competition. This should be WASTE/USED chemicals only. Chemicals must be made safe by the team for disposal in one of the listed waste classifications on the Team Waste Tag form. This section should exactly match the information on your waste tags. Team Waste Tags must be present to race and completed to be allowed to dispose of chemicals. See Team Waste Tags section of EDP.

Waste Description	Concentration (Include units!)	Amount (MUST include units!)	Disposal Waste Stream* (Flammable, Acid, Aqueous [pH 6-9], Organic, Base, Solids [pH 6-9], Other*) *Only 1 classification may be selected **If Other, classification must be specified
Agarose gel dipped in KOH	3% agarose, 8 M KOH	500-700 ml	Base
Residual Al(OH)3 sludge (anode waste)	Al(OH)3 ppt. (unknown conc.)	50 g	Solids (ph 6-9)
PVDF based cathode scrap	PVDF + activated carbon + DMF pasted on steel mesh in the ratio (1g : 2g : 12ml), final conc. unknown.	50-100g	Organic
Iodine Clock reaction waste	KI 0.2M, H2O2 30%, H2SO4 0.5M, starch solution 1%, Sodium thiosulphate 0.1M	<100ml	Other

Chemical Hazards and Disposal

Chemical Properties and Hazards for ALL CHEMICALS, including reactants, intermediates, products, and lubricants.

Chemical Name	Physical State	GHS Hazard Classifications*	Incompatible Chemicals List chemicals present within the laboratory	Flash Point Temp.	Flammability Limits	
					LFL	UFL
Activated Carbon Powder	solid	Not Classified	Strong oxidizers like $KMnO_4$, H_2O_2, H_2SO_4	NA	NA	NA
PVDF Polymer	liquid	Not Classified	Strong oxidizers (e.g., concentrated H_2SO_4, HNO_3, $KMnO_4$), heat above decomposition temp	NA	NA	NA
DMF	liquid	H225 (Highly flammable), H319 (Eye irritation), H361 (Suspected of damaging fertility or the unborn child), H373 (Organs through prolonged exposure), H332 (Harmful)	DMF, KI, H_2O_2, organics, water (reactive with water)	~58°C (closed cup)	2.2%	16%

KMnO4	solid	H272 (Oxidizing solid), H302 (Harmful if swallowed), H314 (Causes severe skin burns and eye damage), H410 (Very toxic to aquatic life with long lasting effects)	H_2O_2, DMF, organics (e.g., Activated Carbon, Agarose, Starch)	NA	NA	NA
MnO2	solid	Not classified as hazardous under GHS (may cause mechanical irritation as a dust)	Reducing agents, organics, acids (especially H_2O_2, Sodium Thiosulphate, KI)	NA	NA	NA
Agarose powder	solid	Not Classified	Strong oxidizers like $KMnO_4$, H_2O_2, H_2SO_4	NA	NA	NA
Soluble Starch	solid	Not Classified	Strong oxidizers like $KMnO_4$, H_2O_2, HNO_3	Dust may be explosive in air	NA	NA
KI	solid	H319 (Causes serious eye irritation), H361 (Suspected of damaging fertility or the unborn child)	Oxidizers like H_2O_2, H_2SO_4	NA	NA	NA
H2O2	liquid	H271 (May cause fire/explosion), H302 (Harmful if swallowed), H314 (Causes severe burns), H332 (Harmful if inhaled), H335 (Respiratory irritation)	$KMnO_4$, MnO_2, Activated Carbon, KI, H_2SO_4	>100°C (decomposes before boiling)	NA	NA
H2SO4	liquid	H290 (May be corrosive to metals), H314 (Causes severe burns and eye damage)	DMF, KI, H_2O_2, organics, water (reactive with water)	>100°C (decomposes before boiling)	NA	NA
Sodium Thiosulphate	solid	Not Classified	Strong acids like H_2SO_4	NA	NA	NA

*Complete this section of the EDP using the Globally Harmonized System (GHS) hazard classifications that are indicated on Section 2 of your chemical's SDS. This is NOT the same hazard ranking system as the National Fire Protection Association (NFPA) "Fire Diamond". Note that the GHS hazard ranking system runs opposite to the NFPA "Fire Diamond" system. For example, a Category 4 NFPA hazard is the highest in severity, while a Category 4 GHS hazard is the lowest in severity. For example, for acetic acid (SDS here) you would write in: Flammable Liquid (Category 3), Skin Corrosion (Category 1A), and Serious Eye Damage (Category 1).

Chemical Toxicology, Regulation and Disposal: List the same chemicals that appear above, in the same order.

Chemical Name	**Toxicology**			**Waste Classification for Disposal**	**Personal Protective Equipment Specific to this Chemical**
	8-Hour TWA	**STEL**	**Ceiling**		
Activated Carbon Powder	N/A (nuisance dust limit 10mg/m^3)	N/A	N/A	Solids [pH 6-9]	Lab coat, gloves, dust mask or respirator if airborne
PVDF Polymer	N/A	N/A	N/A	Solids [pH 6-9]	Lab coat, gloves
DMF	10 ppm (skin)	N/A	N/A	Organic	Lab coat, nitrile gloves, safety goggles, fume hood
KMnO4	0.2 mg/m^3	N/A	N/A	Oxidiser / Solids [pH 6-9]	Lab coat, nitrile gloves, safety goggles

MnO_2	0.2 mg/m³	N/A	N/A	Solids [pH 6-9]	Lab coat, gloves, safety goggles
Agarose powder	N/A	N/A	N/A	Solids [pH 6-9]	Lab coat, gloves, dust mask if handling large quantities
Soluble Starch	N/A	N/A	N/A	Solids [pH 6-9]	Lab coat, gloves
KI	N/A	N/A	N/A	Aqueous [pH 6-9]	Lab coat, gloves
H_2O_2	1 ppm	2ppm	N/A	Aqueous [pH 6-9]	Lab coat, gloves, safety goggles
H_2SO_4	1 mg/m³	N/A	3 mg/m³	Acid	Lab coat, gloves, face shield or safety goggles
Sodium Thiosulphate	N/A	N/A	N/A	Aqueous [pH 6-9]	Lab coat, gloves

Biohazards: Provide details below on any biological hazards that may occur during the design, development, preparation or competition phases of your car. Please list the biological hazards, the biohazard level, and a description of how these agents will be safety handled.

This question does not apply, as there are no biohazards present in our car design and mechanism.

Standard / Safe Operating Procedures Page

- Provide step-by-step details for each of the sections shown below.
- Identify the hazards, the control methods and the personal protective equipment (PPE) required.
- Provide adequate detail so that the reviewers of this document will have adequate understanding of your procedure to pass judgment on the safety of your vehicle.

The **Emergency Shutdown** section should have only one or two steps required to stop your vehicle and bring it to a safe state.
The **Start-Up Procedure** section should list all the steps required to prepare your chemicals and vehicle at your preparation table. This must include procedures for making each solution required for your car to operate.
The **Run Time Procedure** should describe all steps to operate your vehicle at the competition starting line, including activation of any switches, valves, etc.
The **Shutdown Procedure** should describe the steps normally taken to shut down your vehicle at the end of your competitive run. This cannot involve disconnecting tubing, removing components of the car, or cutting electrical connections on the race floor.
The **Cleanup / Waste Disposal** section should list all the steps required to clean your vehicle of all chemicals and proper chemical disposal. Please keep in mind that at the competition, you most likely will not be working in a chemistry laboratory or have access to a sink. You should consider what additional supplies and steps will be needed when you are doing clean up at your table at the competition site. Please also list which waste bucket you will be using to dispose of the waste (example: Acids, Bases, Organic, Aqueous, Inert Solid Waste). This must include steps of how any student made electro chemical (battery) devices will be separated, neutralized and made safe prior to disposal in solid waste streams.
The team must also remember that all glassware must be clearly labeled at the competition site. Unlabeled chemicals at the tableside are grounds for disqualification.

Sequence of Steps	Potential Hazards	Procedure to Control Hazard	PPE or Equipment Required
Emergency Shutdown			
• If any leakage, spill, or unexpected reaction is observed before placing the car on track, immediately disconnect the battery terminals to stop the reaction. • Remove aluminium plates from the battery slot to fully terminate any ongoing reaction.	• Contact with KOH electrolyte • Sudden release of hydrogen gas	• Disconnecting stops electrical flow and reaction instantly. • Removing aluminium halts battery function. Perform carefully to avoid splashes.	• Lab coat • Nitrile gloves • Safety goggles
Start-up Procedure			

(1) We need to prepare cathode plates • Mix PVDF polymer into DMF solvent. • Add Activated carbon + MnO_2 to it, mix it and it would form a paste like substance. • Stick it onto a steel mesh. (2) We need to prepare 2% agarose gel in water and then keep it into 8M KOH solution for 1 hr at least (3) Finally we would assemble an aluminium plate with gel and cathode (battery is made now).	• Exposure to DMF solvent vapour (toxic). • Contact with MnO_2 (irritant). • Contact with concentrated KOH (corrosive).	• Handle KOH with care, avoid spills or skin contact. • Assemble battery on stable surface wearing PPE.	• Lab coat • Nitrile gloves • Blotting paper • Safety goggles • (For DMF) Work in ventilated area
Run Time Procedure			
• We will switch on two keys, one is between the electrochemical battery and the motor and the other is between the external battery and then nano/solenoid valve.	• Leakage of KOH electrolyte onto track. • Hydrogen gas evolution (small amount) in a confined area.	• Ensure the battery is sealed properly before placing it on track. • Operate in a ventilated area to safely disperse any hydrogen gas.	• Lab coat • Nitrile gloves • Safety goggles
Shutdown Procedure			
• Prepare iodine clock reagents in required concentrations: – Solution A: H_2O_2 + soluble starch – Solution B: KI + $Na_2S_2O_3$ (sodium thiosulphate) + H_2SO_4 • Mix solutions in the reaction chamber at the start of the run (or as per stopping mechanism design). • Allow reaction to proceed; colour change (clear to deep blue) triggers stopping mechanism (e.g. light sensor). • After stopping, carefully collect reaction mixture for disposal.	• Contact with iodine clock chemicals (H_2O_2 – oxidiser, KI – irritant, H_2SO_4 – corrosive, $Na_2S_2O_3$ – irritant). • Possible spillage during preparation or disposal.	• Prepare solutions in small quantities with care. • Mix only when ready to operate the stopping mechanism. • Collect waste in labelled aqueous waste container.	• Lab coat • Gloves • Safety goggles • Tissue papers • Sorbent papers. • Blotting paper
Cleanup / Waste Disposal			
• Neutralise any residual KOH electrolyte if allowed by competition disposal rules (use dilute acid). • Rinse and dry aluminium plates if required before disposal as solid waste (pH >9). • Collect used KOH electrolyte in Base waste container. • Collect iodine clock reaction waste in an Aqueous waste container. • Clean spills with absorbent pads or paper towels and dispose of contaminated solid waste. • Ensure battery plates are separated, neutralised if needed, and made safe before disposal in solid waste streams. • Label all waste containers clearly at the competition site.	• Contact with hazardous chemical waste (KOH, iodine clock reagents) • Improper disposal leading to environmental contamination	• Follow chemical disposal protocols strictly. • Neutralise before disposal where permitted. • Label and seal all waste containers with waste tags	• Lab coat • Gloves • Safety goggles • Tissue papers • Sorbent papers.

Equipment List

- Please list every piece of equipment on the car.
- Please include all manufacturer's specification documents or specifications for custom-built components in the EDP Supplement document.

Equipment	Manufacturer	Operating Limits: Temperature	Operating Limits: Pressure	Materials incompatible with chemicals?
Aluminium Frame	Generic	Typically till 220C	Not Applicable	Strong Acids, Strong Alkalis
ABS material 3D printed funnel and chamber for iodine clock reaction, gears and battery cabinet.	eSUN	Typically till 75C	Not Applicable	Strong solvents like acetone, ethyl acetate etc.
6V motor	Generic	Not Applicable	Not Applicable	Depends on the motor type
L298N motor driver	Generic	Not Applicable	Not Applicable	Strong Acids, Some solvents
Arduino Nano microcontroller	Arduino	Not Applicable	Not Applicable	Strong Acids, Some solvents
Commercial Battery	Eveready	-20 to 60C	Not Applicable	Depends on Battery Chemistry
Solenoid Valve	Generic	Not Applicable	0.2 to 10 bar	Depends on Valve material and Chemicals
Copper , Jumper Wires	Generic	-40 to 200C	Not Applicable	Strong Acid, Some solvents.
LDR Sensor	generic	-30 to 70C	Not Applicable	Strong Acid, Some solvents
LED Laser Module	generic	-30 to 60C	Not Applicable	Strong Acids
Glass beaker (50 ml)	Spylx	-196 to 400 C	5-20 psi	-Nil-
Wheels	generic	Not Applicable	Not Applicable	Depends on the Wheel Material

Note: It is highly recommended that you include a CAD or other diagram indicating where each piece of equipment is located within the design of your car. Use the same naming scheme in the diagram as in the equipment list."

Discharged Hydrogen (or other flammable chemicals) Calculations

If your car will include a small amount of hydrogen discharge, please use this space to provide calculations to prove to the reviewer that any discharged hydrogen is well below the Lower Flammable Limit (LFL)/Lower Explosive Limit (LEL) of hydrogen for the given volume of the reactor, chamber or fuel cell in which hydrogen is stored. *If your car does not use hydrogen, then this section should be left blank.*

Pressure Calculations

For all cars with pressure greater than 5psig, please complete the following in this section. The textbook "Chemical Process Safety" by Crowl and Louvar can be used as reference. Please see Appendix A of the Safety Rules for full instructions on what is required for Pressure Testing. *If your car does not generate pressure above 5 psig, you may leave this section blank.*

- List of potential credible overpressure scenario(s) (i.e., too much reactant added, blocked valve, etc.)

- Sizing calculations for a pressure relief device. You must calculate both the appropriate pressure relief set point <u>and</u> orifice size/device capacity based on the worst-case overpressure scenario identified above;

- Test procedure and results for pressure relief.

Capital Cost of Vehicle Calculations

Referencing the competition rule surrounding Capital Cost of Vehicle, use the space below to show the capital cost of your vehicle and all related calculations.

Cost will include - Mechanical Parts, Chemical Costs,

Electrical Parts: Motor – ₹700; Motor drivers (2 x ₹209) – ₹418; External battery – ₹100; Nano microcontroller – ₹199; Breadboard – ₹300; Solenoid valve – ₹211; Wheels – ₹200; Wires – ₹50.
Subtotal (Electrical Parts): ₹2,178

Mechanical Parts: Aluminium frame – ₹200; Nuts and bolts – ₹200; ABS roll (for 3D printing) – ₹1,200.
Subtotal (Mechanical Parts): ₹1,600

Chemical Costs: Aluminium sheet (anode) – ₹280; Steel mesh (cathode support) – ₹390; Agarose (50 g used) – ₹2,450; KOH – ₹550.
Subtotal (Chemical Costs): ₹3,670

Total Capital Cost of Vehicle: ₹7,448

Team Waste Tags

Please fill out a waste tag fully describing each of your competition day waste streams, using the form below. This must be completed and included with your EDP. You must print and bring enough copies to accommodate all the waste you might generate. A completely filled out waste tag will be required before any team is allowed to dispose of waste into an AIChE waste collection system.

ALL SOLID WASTE MUST BE DISASSEMBLED, MADE SAFE AND BE LIQUID FREE

Team Name: VIRUS No.: 1
Waste Description:
Agarose gel dipped in KOH

Composition:
3% agarose,
8 M KOH

Disposal Waste Stream (select only 1):
☐ Flammable ☐ Organic
☐ Acid ☑ Base
☐ Aqueous (pH 6-9) ☐ Solids (pH 6-9)

Notes:

Team Name: VIRUS No.: 2
Waste Description:
Residual Al(OH)3 sludge (anode waste)

Composition:
Al(OH)3 ppt. (unknown conc.)

Disposal Waste Stream (select only 1):
☐ Flammable ☐ Organic
☐ Acid ☐ Base
☐ Aqueous (pH 6-9) ☑ Solids (pH 6-9)

Notes:

Team Name: VIRUS No.: 3
Waste Description:
PVDF based cathode scrap

Composition:
PVDF + activated carbon + DMF pasted on steel mesh in the ratio (1g : 2g : 12ml), final conc. unknown.

Disposal Waste Stream (select only 1):
☐ Flammable ☑ Organic
☐ Acid ☐ Base
☐ Aqueous (pH 6-9) ☐ Solids (pH 6-9)

Notes:

Team Name: VIRUS No.: 4
Waste Description:
Iodine Clock reaction waste

Composition:
KI 0.2M, H2O2 30%, H2SO4 0.5M, starch solution 1%, Sodium thiosulphate 0.1M

Disposal Waste Stream (select only 1):
☐ Flammable ☐ Organic
☐ Acid ☐ Base
☐ Aqueous (pH 6-9) ☐ Solids (pH 6-9)
☑ Other

Notes: