Electrochemical Reduction of Carbon Dioxide to Useful Chemical Intermediates

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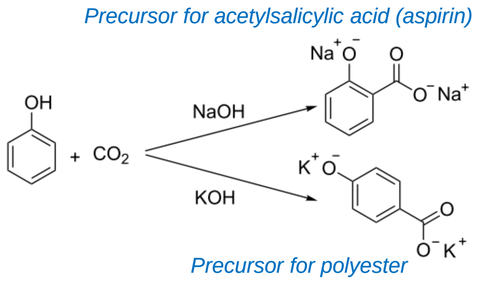
Background and Motivation

The recycling of captured CO_2 as a chemical feed stock is an attractive reuse and recovery strategy. The direct insertion of CO_2 is a route to an increased chain length and the production of valuable chemical intermediates.

- **CO_2 reuse as an intermediate has been limited by its high thermodynamic stability.**
  - **High temperatures and pressures are necessary to activate the CO_2**
  - **The use of complex reactive catalysts/organometallic reagents are also typically required**

Precursor for acetylsalicylic acid (aspirin)

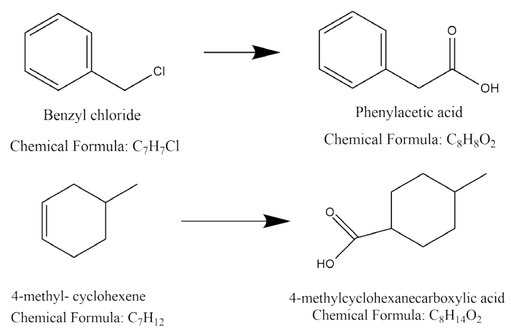


Kolde-Schmidt reaction can be used to achieve valuable polymer and pharmaceutical intermediates

Precursor for polyester

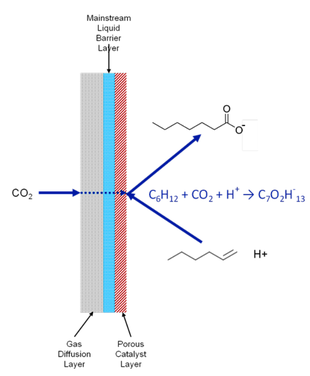
Mainstream's Approach

- **Electrocarboxylation provides an accessible, flexible low temperature, low energy path to CO_2 reuse**

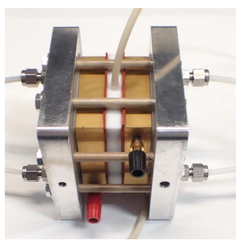


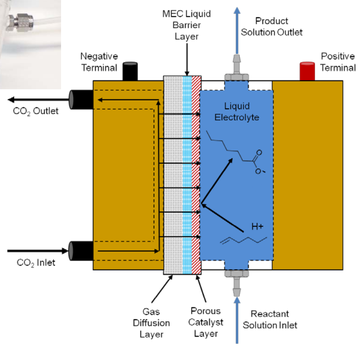
Wide range of reactions have been demonstrated

- **The main issue is CO_2 solubility limits the reaction rates**
- **Mainstream's approach maximizes CO_2 mass transport using highly optimized gas diffusion electrodes.**



Mainstream's electrode design incorporates a high performance liquid barrier layer which maximizes the performance



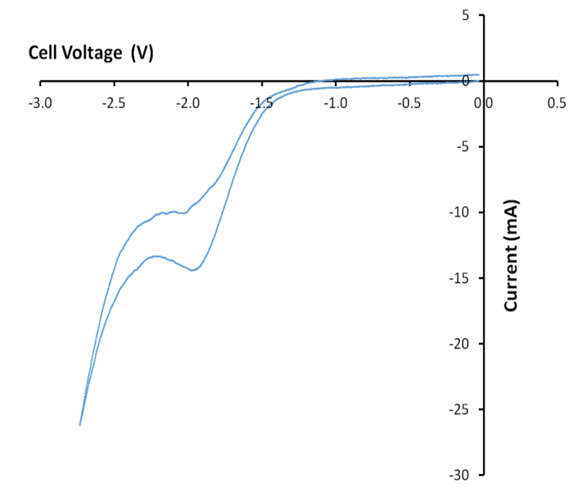


Phase I cell design incorporating gas distribution electrode

Electrochemical Measurements

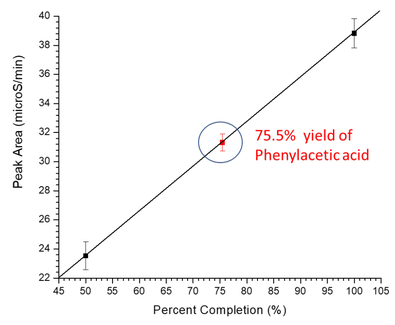
- **CO_2 can effectively be electrochemically activated at room temperature and pressure in the presence of a wide range of organic precursors and solvents**

Clear reduction electrochemical behavior shown for a range of catalyst and solvent systems



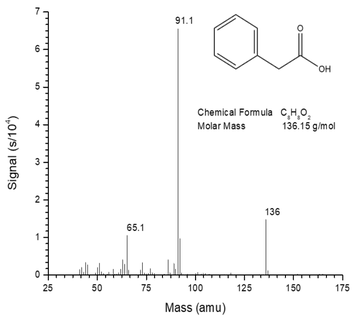
Electrosynthesis Runs

- **Bench-scale controlled-current electrosynthesis runs performed for a range of precursors using a 25 cm^2 electrode area batch reactor**

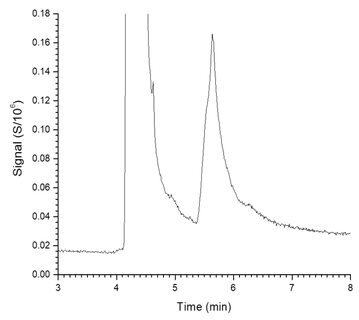


Quantitative analysis of Phenyl Acetic Acid Yield

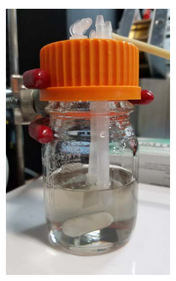
75% yield at an 80% Faradaic efficiency



GC-MS confirms the target product

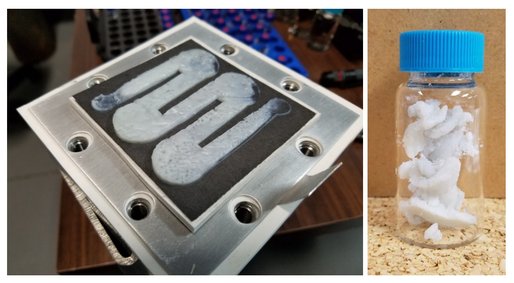


Quantitative analysis by ion chromatography



Solution Reservoir at Start

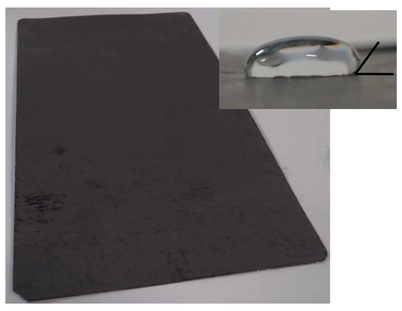
Solution Reservoir Clouded with Precipitating Product



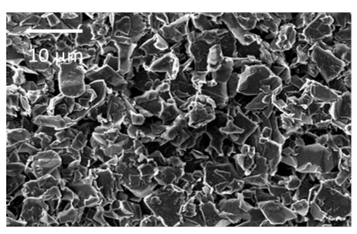
High yield of reaction product obtained for model electrocarboxylation of benzyl chloride

Electrode Coating and Catalyst Selection

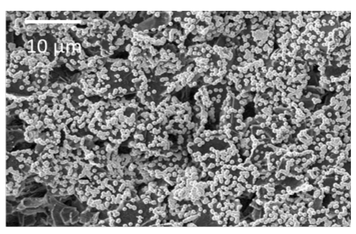
- **Mainstream has optimized the liquid barrier layer coating – to prevent electrode flooding thus maximizing performance**
- **Stable catalyst coatings have been developed for maximum selectivity and current density (reaction rate)**



Low porosity, hydrophobic gas diffusion electrodes scaled to 240 cm^2 active area



Uncoated Mainstream GDL



Catalyst coated Mainstream GDL

Conclusions

- **Reproducibly fabricated high performance electrodes utilizing catalyst-coated Mainstream optimized liquid barrier-gas diffusion layer substrates**
- **Scaled the optimized GDL substrates to 240 cm^2 active area**
- **Demonstrated CO_2 reduction and electrocarboxylation with a range of precursors using a 25 cm^2 active area bench scale cell**
- **Achieved unoptimized yields of 75% with a Faradaic efficiency of 80% for the electrocarboxylation of benzyl chloride to phenyl acetic acid.**

Acknowledgements

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