



CARBON DIOXIDE CAPTURE WITH BOROHYDRIDES

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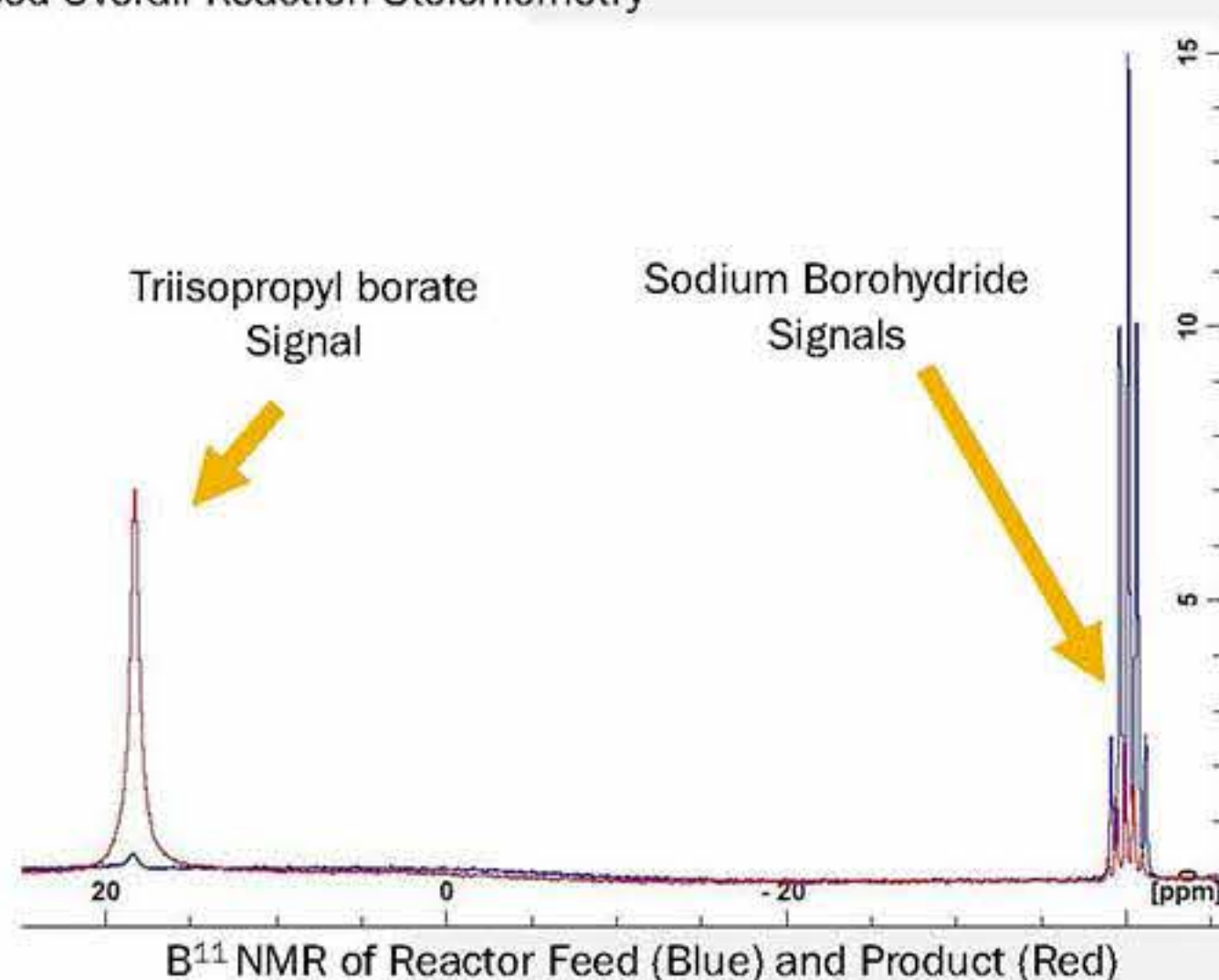
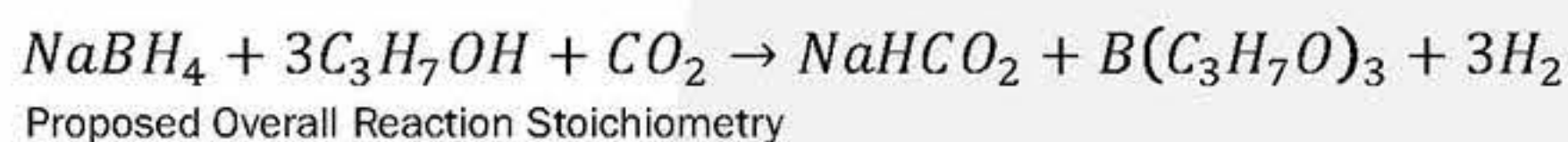


Introduction

- Carbon dioxide (CO_2) can be reacted with sodium borohydride (NaBH_4) in isopropanol to form liquid triisopropyl borate, solid sodium formate, and gaseous hydrogen (H_2).
- Objective 1 was to demonstrate the feasibility of reacting CO_2 with NaBH_4 .
- Objective 2 was to scale-up the capture of CO_2 and design a process plant for commercial applications.

Reactive Carbon Dioxide Capture

- NaBH_4 dissolved in isopropanol ($\text{C}_3\text{H}_7\text{OH}$) reacts with CO_2 upon gas absorption.
- Major product is sodium formate (NaHCO_2), minor product of isopropyl borate ($\text{BH}_2(\text{C}_3\text{H}_7\text{O})$); continuous reaction of $\text{BH}_2(\text{C}_3\text{H}_7\text{O})$ with $\text{C}_3\text{H}_7\text{OH}$ leads to triisopropyl borate ($\text{B}(\text{C}_3\text{H}_7\text{O})_3$) and H_2 .

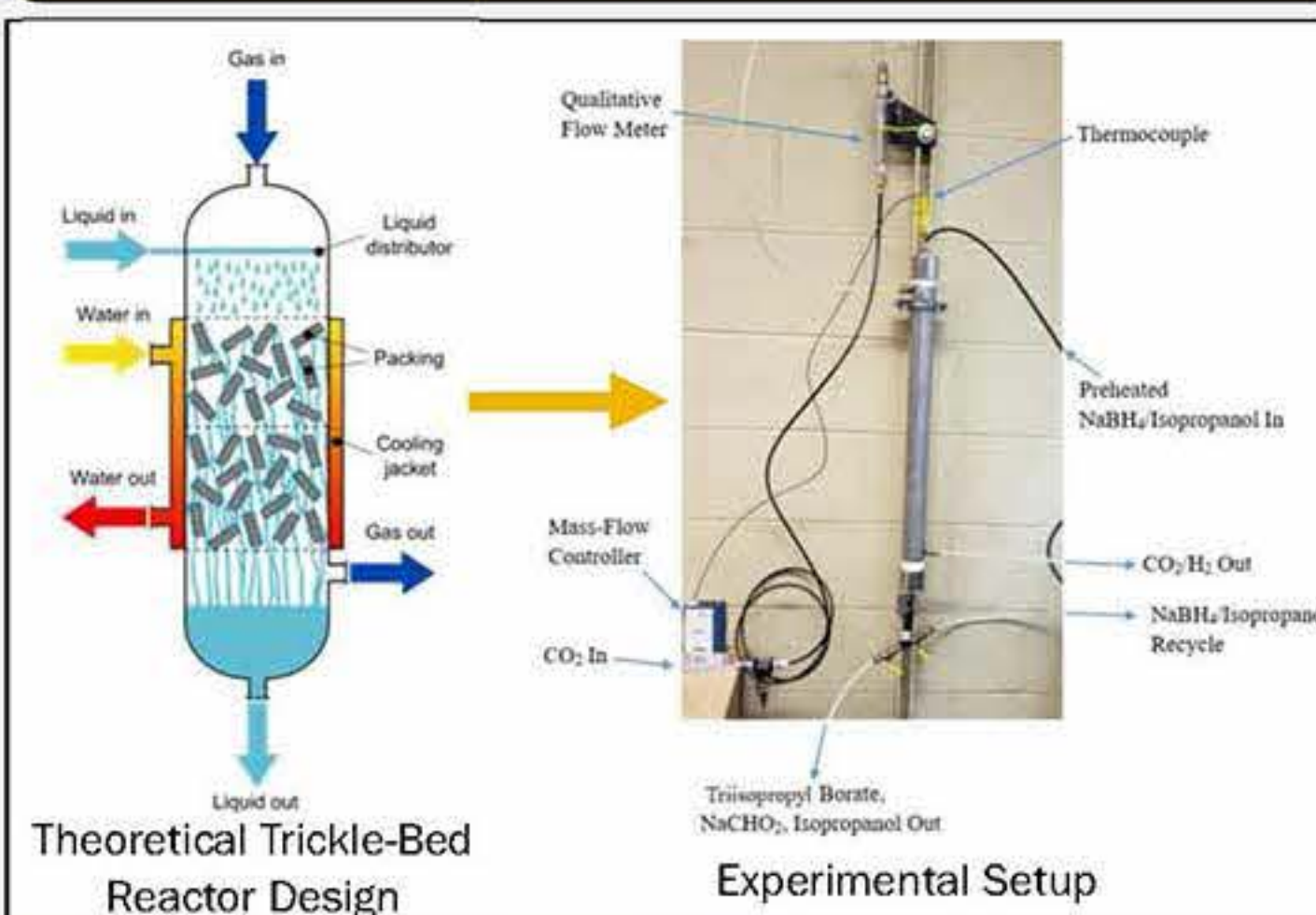


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Reactor Design

- Absorption of CO_2 limits reaction.
- Trickle-bed reactor chosen to maximize gas phase mass transfer.
- Column hydrodynamics increase total possible wetting of packing.
- Solution/reactor heated to 45°C to maximize gas phase mass transfer.
- Operated via concurrent downward flow.



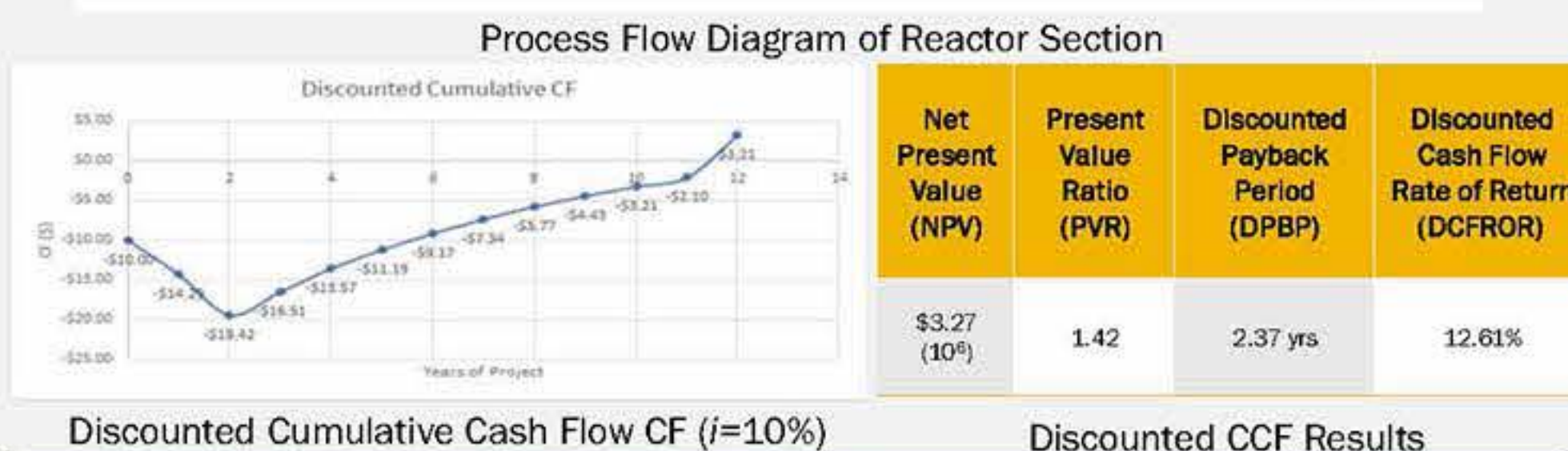
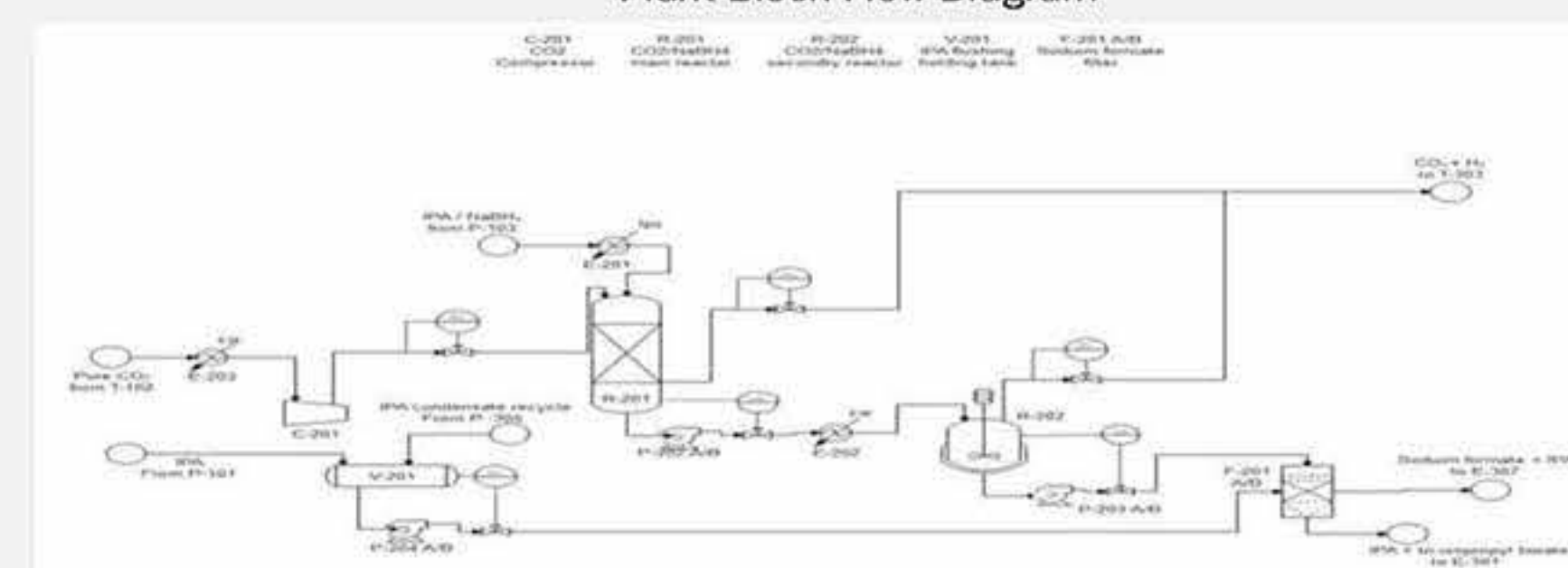
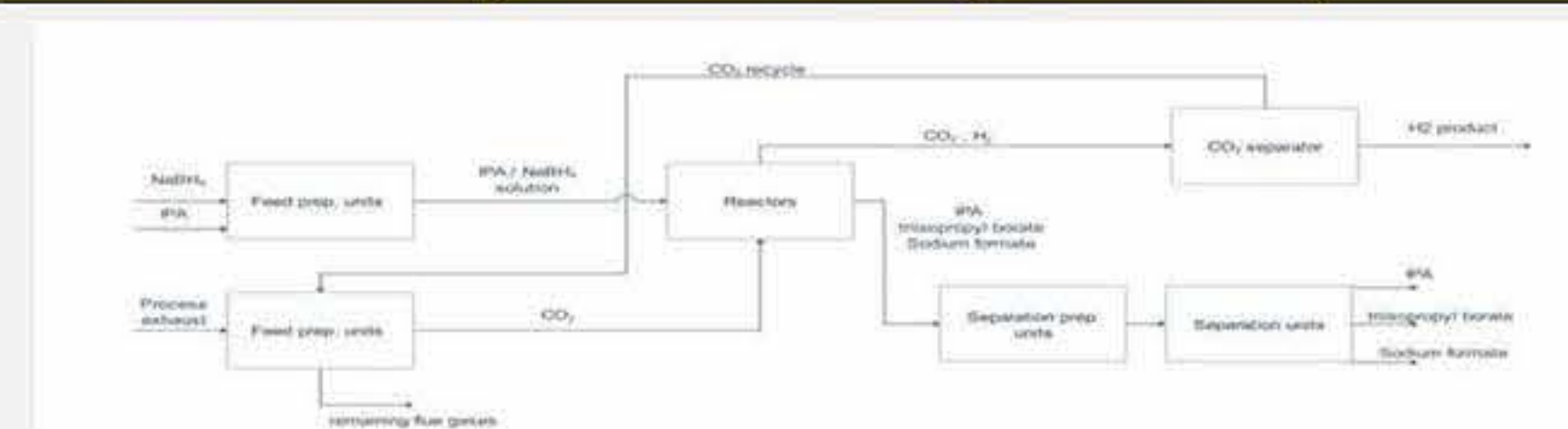
Results

- Results show very high conversion of NaBH_4 above 1:1 ratio.
- Over 50% conversion at 0.47:1 ratio implies a greater than 1:1 reaction.
- Additional work needed to validate proposed reaction stoichiometry.

NaBH_4/IPA Flow Rate (mL/s)	CO_2 Flow Rate (sccm)	Molar Flow Ratio (mol CO_2 :mol NaBH_4)	Conversion of NaBH_4 (%)
1.05	905	4.74	100
1.05	334	1.74	100
1.05	330	1.69	100
1.05	247.3	1.14	100
1.05	123.7	0.474	80.87

Process Plant Design

- Main assumptions: CO_2 sourced from industrial flue gas (coal), NaBH_4 purchased, reactants are dry.
- Continuous process operating at 350 days per year.
- Chemical Engineering Plant Cost Index: 603.1
- Production target: 10^6 kg of sodium formate.
- Potential design for carbon negative facility.



Discounted Cumulative Cash Flow CF ($i=10\%$)

Discounted CCF Results

Conclusions

- Objectives 1 and 2 accomplished.
- CO_2 capture process is feasible for converting large quantities of CO_2 continuously.
- Design is easily added to existing processes which could greatly reduce industrial greenhouse emissions.

Future Work

- Vary CO_2 concentration to better simulate flue gases.
- Further elucidation of mechanism/stoichiometry.
- Increased operational pressure to increase mass transfer.