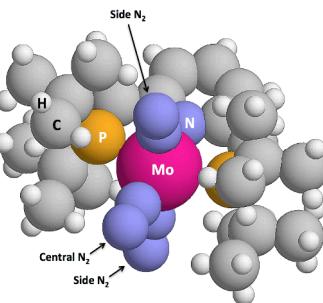




Nitrogen/Oxygen Battery

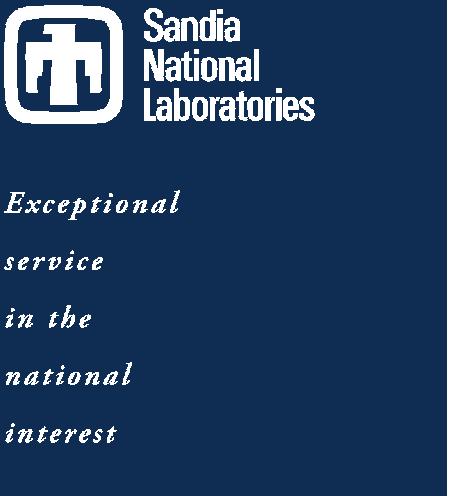
A Transformational Architecture for Large Scale Energy Storage



US DOE Energy Storage Systems Research Program

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N_2/O_2 Battery Project Overview

- Air/Air battery.
- N_2 electrochemistry enables the redefinition of a gas (diffusion) electrode and the three phase interface.
- Operated as redox flow battery.
- Provide a very high energy density, very low cost, environmentally benign electrochemical platform for load leveling and for grid-integrated storage of energy generated by wind, solar and other sustainable but intermittent sources.
- Project requires a reversible N_2 electrode.

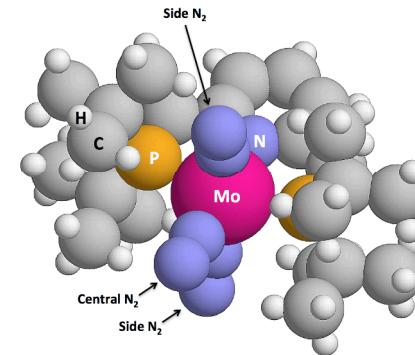
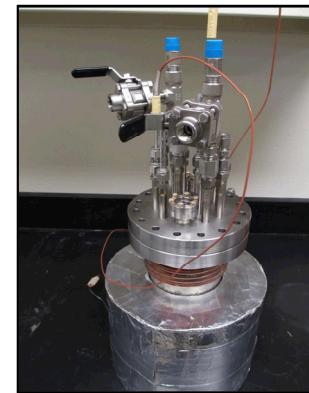
Anode requires the reversible electrochemical reduction/oxidation of N_2 .

Three approaches to achieve N_2 reduction (nitrogen fixation).

- 1) Direct reversible reduction/oxidation of N_2 to $2N^{3-}$ in molten salt at $+ 400^\circ C$.

- 2) Mediated and catalyzed reduction of N_2 to NH_3 and subsequent utilization of the NH_3 as the anode in an NH_3 /air fuel cell.

- 3) Indirect reversible reduction/oxidation of N_2 to $2N^{3-}$ at ambient temperature.



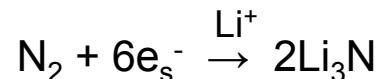
Indirect Reduction of N₂ at Ambient Temperature.

At ambient temperature N₂ is not directly reduced on any electrode in any electrolyte.

Some researchers have achieved Li mediated reduction of N₂ by the exposure of N₂ to electrodeposited Li metal.



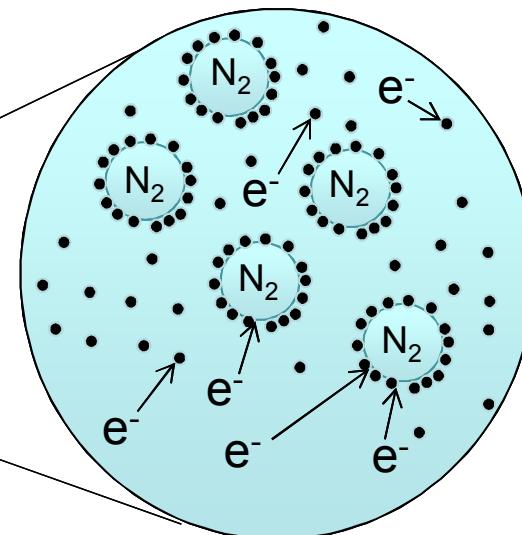
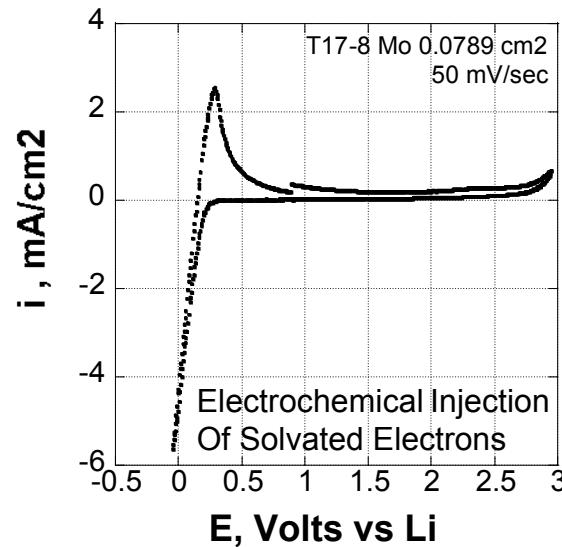
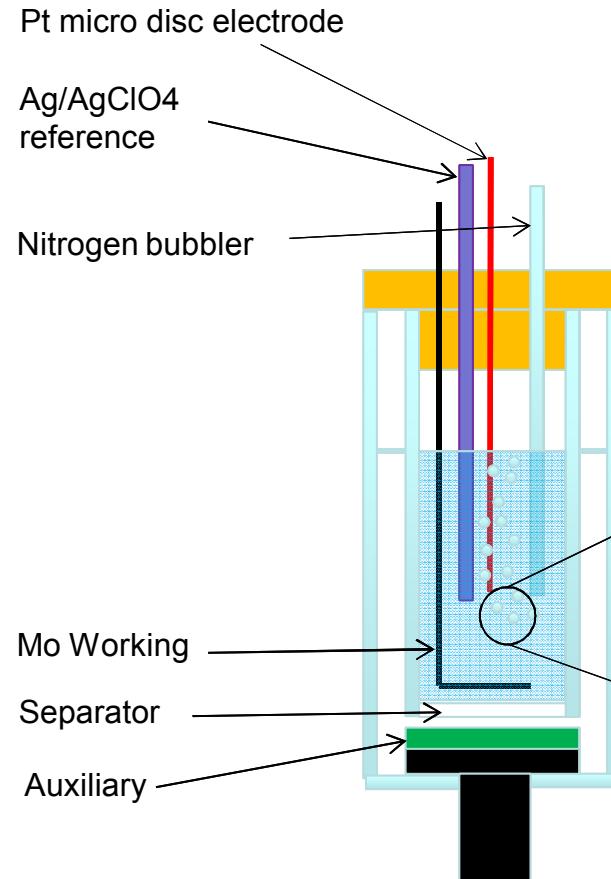
Our approach: Reduce N₂ in a solution of solvated electrons [e_s⁻].



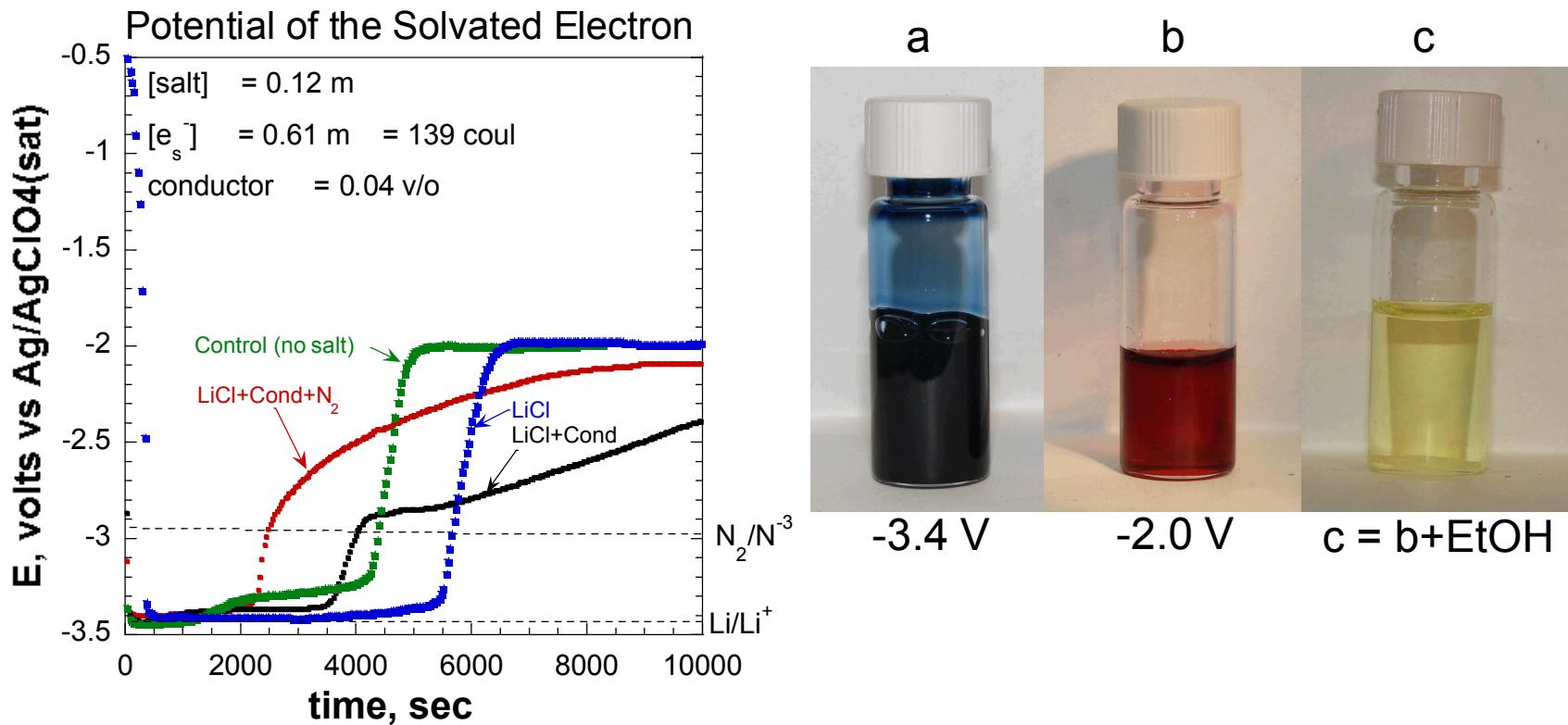
Reduction does not occur at the electrode surface.
Advantage: Gas diffusion electrode not required.

Indirect Reduction of N_2 .

Concept Illustration



Stabilization of the Solvated Electron [e_s^-] at High Negative Potential Enables the Reduction of N_2



Summary/Conclusions

- 1) Demonstrated reversible redox for N_2/N^{-3} in LiCl-KCl at 450 C
Developed procedure for large scale purification of LiCl-KCl eutectic.
- 2) Density Functional Theory (DFT) has been used to analyze the path to NH_3 synthesis on the Arashiba *et. al.* catalyst.
Paper submitted for publication (Peter Feibelman, J. Phys. Chem.).
- 3) Developed an electrolyte which stabilizes solvated electrons for the subsequent indirect reduction of N_2 .

Future Tasks

- Couple N_2/N^{-3} and O_2/O_2^- reactions in LiCl-KCl electrolytes to produce N_2/O_2 battery prototypes.
- Continue stabilization of solvated electrons at high negative potential and introduce catalysts to enhance N_2 reduction.
- Identify procedures for chemical analysis of N_2 reduction products.
- Identify appropriate cation to enable the oxidation of N^{-3} .

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Discussions on electrochemical stability of electrolytes and solvated electrons.
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